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Abstract: This volume represents the proceedings of the Main Conference, with Posters and Demonstrations track, of the 14th International Conference on ICT in Education, Research, and Industrial Applications, held in Kyiv, Ukraine, in May 2018. It comprises 47 contributed papers that were carefully peer-reviewed and selected from 119 submissions. The volume opens with the abstracts of the two keynote talks. The rest of the collection is organized in six parts. Parts II to V contain the contributions to the Main ICTERI Conference tracks, structured in four topical sections: (I) Advances in ICT Research; (II) Information Systems: Technology and Applications; (III) Academia/Industry ICT Cooperation; and (IV) ICT in Education. Part VI presents the concise descriptions of the given tutorials. Part VII comprises the contributions of Posters and Demonstrations track.

Keywords: ICT, Advances in ICT Research, ICT Research Infrastructure, Information System, Technology, ICT Application, ICT n Education, ICT-Enabled Cooperation

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ICT in Education, Research and Industrial Applications

Proceedings of the 14th International Conference, ICTERI 2018. Volume I: Main Conference

Kyiv, Ukraine
May, 2018

Ermolayev, V., Suárez-Figueroa, M. C., Ławrynowicz, A., Palma, R., Yakovyna, V., Mayr, H. C., Nikitchenko, M., and Spivakovsky, A. (Eds.): ICT in Education, Research and Industrial Applications. Proc. 14th Int. Conf. ICTERI 2018. Volume I: Main Conference. Kyiv, Ukraine, May 14-17, 2018, CEUR-WS.org, online

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Preface

It is our pleasure to present you the proceedings of the Main Conference of ICTERI 2018, the fourteenth edition of the International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications, held in Kyiv (Ukraine) on May 14-17, 2018. This year's edition focused on research advances, information systems technologies and applications, business/academic applications of Information and Communication Technologies. Emphasis was also placed on the role of ICT in Education. These aspects of ICT research, development, technology transfer, and use in real world cases are vibrant for both the academic and industrial communities.

The ICTERI 2018 Main Conference was structured into four thematic tracks reflecting these research fields. In addition, the final part of the proceedings volume contains the extended abstracts of the poster papers which constituted the program of our Posters and Demonstrations Track.

The conference program was complemented by two keynote talks, an invited tutorial, PhD Symposium, poster and demo track, industrial IT Talks sub-event, and five co-located workshops. The proceedings of the PhD Symposium and co-located workshops were published as separate volumes.

The first keynote talk given by Dr. Steffen Lohmann, a senior researcher at the Fraunhofer Institute for Intelligent Analysis and Information Systems as well as associate member of the Smart Data Analytics group at the University of Bonn. His talk was focused on augmenting educational material with knowledge graphs. The second keynote talk was given by Prof. Rajendra Akerkar from Western Norway Research Institute. This talk was about unlocking value from ubiquitous data. The invited tutorial was a focused training on the use of the SlideWiki as an Open Education Platform. It was given by Dr. Klaas Andries de Graaf, a post-doctoral researcher at Vrije Universiteit Amsterdam, and Benjamin Wulff, a researcher at Fraunhofer Institute for Intelligent Analysis and Information Systems.

The rationale behind the Ph.D. Symposium sub-event is to offer an expert environment for the presentation of the tractable ideas and early results of PhD projects or other research aiming at receiving a PhD. Young researchers joined the Symposium to take part in discussions and/or present their papers. They were offered a rare opportunity to exchange and discuss their research ideas with their peers, supervisors, and senior scientists working in the fields within the scope of ICTERI 2018.

Posters and Demonstrations track at ICTERI 2018 called for software demonstrations, interactive models, real-time visualizations, novel technology applications. The

12 selected posters, whose extended abstracts were included in this volume, have been presented in two poster sessions.

Overall ICTERI 2018 Main Conference, including Posters and Demonstrations track, attracted 119 paper submissions, which constituted a 100 percent increase compared to the previous year. Out of these submissions, we have accepted:

- 35 high quality and most interesting papers for the Main Conference program, with the acceptance rate of 34 percent
- 12 best poster presentations, with the acceptance rate of 75 percent

These papers and extended abstracts were published in this Volume I of ICTERI 2018 proceedings.

The conference would not have been possible without the support of many people. First of all, we would like to thank all the authors who submitted papers to ICTERI 2018 and thus demonstrated their interest in the research problems within our scope. We are very grateful to the members of our Program Committee for providing timely and thorough reviews and, also, for being cooperative in doing additional review work. We would like to thank the local organizers of the conference whose devotion and efficiency made this instance of ICTERI a very interesting and effective scientific forum.

May, 2018

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Augmenting Educational Material with Knowledge Graphs

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Abstract. Knowledge graphs represent information in a highly structured and semantically enriched form that allows for advanced querying, reasoning, and information integration. They enable a more intelligent and meaningful analysis of information by focusing on how things are related and by supporting knowledge discovery. Combined with visual interfaces, users are equipped with powerful means to interactively explore information and gain new knowledge from it. This talk will shed light on the power and potential of knowledge graphs in educational contexts. It will reflect on how knowledge graphs can be derived from educational material and effectively support learners in reasoning, sense-making, and understanding.

Keywords: knowledge graph, information analysis, knowledge discovery, visual interface, interactive information exploration, education, learner support.

Unlocking Value from Ubiquitous Data

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Abstract. Data is growing at an alarming rate. This growth is spurred by varied array of sources, such as embedded sensors, social media sites, video cameras, the quantified-self and the internet-of-things. This is changing our reliance on data for making decisions, or data analytics, from being mostly carried out by an individual and in limited settings to taking place while on-the-move and in the field of action. Unlocking value from data directs that it must be assessed from multiple dimensions. Data's value can be primarily classified as “information,” “knowledge” or “wisdom”. Data analytics addresses such matters as what and why, as well as what will and what should be done. In recent days, data analytics is moving from being reserved for domain experts to becoming necessary for the end-user. However, data availability is both a pertinent issue and a great opportunity for global businesses. In effect, data ubiquity is helping manufacturers, retailers, mobility sector and logistics firms, for example, foster an integrated decision-making environment supporting real-time, information-based business networks. New IT architectures enabled by big data, internet-of-things, cloud computing, and other technologies are helping optimize a business environment with common real-time data, workflow, and alerting capabilities. Business success will be centered around the timely and effective analysis of the large-scale data sets generated by business and sensor networks and the ways in which organizational insights are used to assess and affect potential impacts and risks to their business. This talk will present recent examples from work in our research team on ubiquitous data analytics and open up to a discussion on key questions relating methodologies, tools and frameworks to improve ubiquitous data team effectiveness as well as the potential goals for a ubiquitous data process methodology. Finally, we give an outlook on the future of data analytics, suggesting a few research topics, applications, opportunities and challenges.

Keywords: Big data, analytics, ubiquitous, internet-of-things, supply chain, business, mobility sector.

Refining Terminological Saturation using String Similarity Measures

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Abstract. This paper reports on the refinement of the THD algorithm, developed in the OntoElect framework. This baseline THD algorithm used exact string matches for key term comparison. It has been refined by introducing an appropriate string similarity metric for grouping the terms having similar meaning and looking similar as text strings. To choose the most appropriate metric, several existing metrics have been cross-evaluated on the developed test set of multi-word terms in English. The rationale for creating this test set is also presented. Further, the refined algorithm for measuring terminological difference has been cross-evaluated with the baseline THD algorithm. For this cross-evaluation, the bags of terms extracted from the TIME collection of scientific papers were used. The experiment revealed that using the refined algorithm yielded better and quicker terminological saturation, compared to the baseline.

Keywords: Automated Term Extraction, OntoElect, Terminological Difference, Key Term, Linguistic Similarity Metric, Bag of Terms, Terminological Saturation.

1 Introduction

The research presented in this paper is the part of the development of the methodological and instrumental components for extracting representative (complete) sets of significant terms from the representative sub-collections of textual documents having minimal possible size. These terms are further interpreted as the required features for engineering an ontology in a particular domain of interest. Therefore, it is assumed that the documents in a collection cover a single and well circumscribed domain. The main hypothesis, put forward in this work, is that a sub-collection can be considered as representative to describe the domain, in terms of its terminological footprint, if any additions of extra documents from the entire collection to this sub-collection do not noticeably change this footprint. Such a sub-collection is further considered as complete and therefore yields a representative bag of significant terms describing its domain. The approach to assess the representativeness does so by evaluating terminological saturation in a document (sub-)collection [1], [31].

Detecting saturation is done by measuring terminological difference (*thd*) among the pairs of the consecutive incrementally enlarged datasets, as described in Section 4. This set measure is of course based on measuring differences between individual terms. A (baseline) THD algorithm [1] has been developed and implemented in the OntoElect project[1]. This THD algorithm, however, uses a simple string equivalence check for detecting similar individual terms. The objective of the research presented in this paper was to find out if it is possible to achieve better performance in measuring terminological difference by using a proper string similarity measure to compare individual terms.

The remainder of the paper is structured as follows. Section 2 reviews the related work. Section 3 reports on the implementation of the chosen string similarity measures and selecting the proper term similarity thresholds for their use. Section 4 sketches out the approach of OntoElect for measuring *thd* and our refinement of the baseline THD algorithm. Section 5 presents the set-up and results of our evaluation experiments. Our conclusions and plans for the future work are given in Section 6.

2 Related Work

The work reported in this paper aims at improving the measures of terminological difference between the bags of terms extracted from textual documents. The improvement is sought via the proper choice and use of existing string metrics for measuring linguistic (dis)similarity between extracted terms, as opposed to the baseline THD algorithm [1] which uses text string equality measures for comparing terms. It is also the premise in our approach that the bags of terms are multi-word, extracted from plain text files, and accompanied by numeric significance (rank) values. The terms are also expected to be English. Therefore, the work related to the presented research is sought in automated term extraction (ATE) from English texts and string similarity (distance) measurement of the pairs of text strings containing one to several words.

In the majority of approaches to ATE, e.g. [2] or [3], processing is done in two consecutive phases: Linguistic Processing and Statistical Processing. Linguistic processors, like POS taggers or phrase chunkers, filter out stop words and restrict candidate terms to n-gram sequences: nouns or noun phrases, adjective-noun and noun-preposition-noun combinations. Statistical processing is then applied to measure the ranks of the candidate terms. These measures are [4] either the measures of “unithood”, which focus on the collocation strength of units that comprise a single term; or the measures of “termhood” which point to the association strength of a term to domain concepts.

For “unithood”, the metrics are used such as mutual information [5], log likelihood [6], t-test [2], [3], the notion of ‘modifiability’ and its variants [7], [3]. The metrics for “termhood” are either term frequency-based (unsupervised approaches) or reference corpora-based (semi-supervised approaches). The most used frequency-based metrics

1 https://www.researchgate.net/project/OntoElect-a-Methodology-for-Domain-Ontology-Refinement

are TF/IDF (e.g. in [8], [9]), weirdness [10] which compares the frequency of a term in the evaluated corpus with that in the reference corpus, domain pertinence [11]. More recently, hybrid approaches were proposed, that combine "unithood" and "termhood" measurements in a single value. A representative metric is c/nc-value [12]. C/nc-value-based approaches to ATE have received their further evolution in many works, e.g. [2], [11], [13] to mention a few.

Linguistic Processing is organized and implemented in a very similar fashion in all ATE methods, except some of them that also include filtering out stop words. Stop words could be filtered out also at a cut-off step after statistical processing. So, in our review and selection we look at the second phase of Statistical Processing only. Statistical Processing is sometimes further split in two consecutive sub-phases of term candidate scoring, and ranking. For term candidates scoring, reflecting its likelihood of being a term, known methods could be distinguished by being based on (c.f. [8]) measuring occurrences frequencies (including word association), assessing occurrences contexts, using reference corpora, e.g. Wikipedia [14], topic modelling [15], [29].

Perhaps the most cited paper that compares string similarity (distance) metrics is [17]. In their cross-evaluation aimed at finding the proper metric for approximate name matching in databases, the authors of [17] used two metric functions based on edit distance: Levenstein distance [18]; and Monger-Elkan distance [19] metrics. Among the metrics based on other principles, they also mentioned Jaro [20], Jaro-Winkler [21] metrics; token-based Jaccard similarity index [22], TF/IDF based cosine similarity and several other corpus-based metrics.

The authors of [23] also acknowledge that there is a rich set of string similarity measures available in the literature, including character n-gram similarity [24], Levenstein distance [15], Jaro-Winkler measure [21], Jaccard similarity [22], tf-idf based cosine similarity [25], and Hidden Markov Model-based measure [26].

To the best of our knowledge, none of the published techniques in ATE use text string similarity (distance) measures to group linguistically similar terms. This is done in the work presented in this paper. Furthermore, none of the techniques, except OntoElect [1], [16], use terminological saturation measures to minimize the sets of documents necessary for extracting the bags of terms which represent a domain.

3 Implementation of String Similarity Measures and the Choice of Term Similarity Thresholds

From the variety of metrics, mentioned above, due to the specifics of our task of the approximate comparison of short strings containing a few words, we filtered out those: (i) that require long strings or sets of strings of a considerably big size; (ii) that are computationally hard. We also tried to keep the representatives of all kinds of string metrics in our short list as much as it was possible. As a result, we formed the following list of measures to be considered for further use:

- Levenstein distance, Hamming distance [27], Jaro similarity, and Jaro-Winkler similarity – edit distance based syntactic measures

- Jaccard similarity index – a token based measure
- Sørensen-Dice coefficient [28] – a bi-gram comparison based measure

Among those, Levenstein and Hamming distances appeared to be the least appropriate in our context due to their limitations. Levenstein returns an integer number of required edits, while the rest of the measures return normalized reals. So, it has not been clear if normalizing Levenstein would really make the result comparable to the other measures in a way to use the same term similarity threshold. Hamming is applicable only to the strings of equal lengths. So, adding spaces to the shorter string would really lower the precision of measurement. Therefore, it has finally been decided to use Jaro, Jaro-Winkler, Jaccard, and Sørencen-Dice for implementation and cross-evaluation in our work. Further, it is briefly explained how should the selected measures be computed and referred to their implementation code. After that, it is explained how term similarity thresholds have been chosen for these implemented measures.

Jaro similarity sim_j between two strings S_1 and S_2 is computed (1) as the minimal number of one character transforms to be done to the first term (string) for getting the second string in the compared pair.

$$sim_j = \begin{cases} 0, & if \quad m = 0 \\ 1/3 * (\frac{m}{|S_1|} + \frac{m}{|S_2|} + \frac{m-t}{m}) & otherwise \end{cases}, \tag{1}$$

where: $|S_1|$, $|S_2|$ are the lengths of the compared strings; m is the number of the matching characters; and t is the half of the number of transposed characters. The characters are matching if they are the same and their distance from the beginning of the string differs by no more than $\lfloor max(|S_1|, |S_2|)/2 \rfloor - 1$. The number of matching but having different sequence order symbols is the number of transposed characters.

Jaro-Winkler similarity measure $sim_{j\text{-}w}$ refines Jaro similarity measure sim_j by using a prefix scale value p which assigns better ratings to the strings that match from their beginnings for a prefix length l. Hence, for the two strings S_1 and S_2 it is computed as shown in (2).

$$sim_{j\text{-}w} = sim_j + l*p*(1 - sim_j), \tag{2}$$

where l is the length of a common prefix (up to a maximum of 4 characters); p is a constant scaling factor for how much the similarity value is adjusted upwards for having common prefixes (up to 0.25, otherwise the measure can become larger than 1; [21] suggests that p=0.1).

Sometimes Winkler's prefix bonus $l*p*(1 - sim_j)$ is given only to the pairs having Jaro similarity higher that a particular threshold. This threshold is suggested [21] to be equal to 0.7.

Jaccard similarity index sim_{ja} is a similarity measure for finite sets, characters in our case. It is computed, for the two strings S_1 and S_2, as the ratio between the cardinalities of the intersection and union of the character sets in S_1 and $S2$ as shown in (3).

$$sim_{ja} = (|S_1| \cap |S_2|)/(|S_1| \cup |S_2|) \tag{3}$$

Finally, Sørensen-Dice coefficient, regarded as a character string similarity measure, is computed by counting identical character bi-grams in S_1 and S_2 and relating these to the overall number of bi-grams in both strings – as shown in (4).

$$sim_{sd} = 2n_{\equiv} / (n_{S_1} + n_{S_2}), \tag{4}$$

where: $n_{\equiv}$ is the no of bi-grams found in S_1 and also in S_2; n_{S_1}, n_{S_2} are the numbers of all bi-grams in S_1 and S_2.

The functions for all four string similarity measures have been implemented[2] in Python 3.0 and return real values within [0, 1].

For the proper use of those functions it is however necessary to determine what would be a reasonable threshold to distinguish between (semantically) similar and not similar terms. For determining that, the following cases in string comparison need to be taken into account:

- Character **strings are fully the same** – **Full Positives (FP)**. This case clearly falls into similar (the same) terms.
- Character **strings are very different** and the terms in these strings carry **different semantics** – **Full Negatives (FN)**. This case is also clear and is characterized by low values of similarity measures.
- Character **strings are partially the same** and the terms in these strings carry the **same or similar semantics** – **Partial Positives (PP)**.

The terms in such strings are similar, though it may not be fully clear. The following are different categories of terms that bring us about this case: words in the terms have different endings (e.g. plural/singular forms); different delimiters are used (e.g. "-", or "–", or " - "); a symbol is missing, erroneously added, or misspelled (a typo); one term is a sub-string of the other (e.g. subsuming the second); one of the strings contains unnecessary extra characters (e.g. two or three spaces instead of one, or noise).

- Character **strings are partially the same** but the terms in these strings carry **different semantics** – **Partial Negatives (PN)**

The terms in such strings are different, though it may not be fully clear. The following are the categories that bring us about this case: the terms carried by the compared strings differ by a few characters, but have different meanings (e.g. "deprecate" versus "depreciate"); the compared terms have common word(s) but fully differ in their meanings (e.g. "affect them" versus "effect them"). These false positives are the hardest case to be detected.

The test set of term pairs falling into the cases described above has been manually developed[3]. For each pair of terms in this test set all four string similarity measures have been computed.

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[2] These functions are publicly available at: https://github.com/EvaZsu/OntoElect

[3] The test set and computed term similarity values are publicly available at https://github.com/EvaZsu/OntoElect/blob/master/Test-Set.xls

We have computed the average values of all four similarity measures for each category using all the test set term pairs falling into this category. The results are given in Table 1.

Table 1: Average similarity measure values for different categories of term pairs from the test set

Case / Category	**Items in Test Set**	**Sørensen-Dice**	**Jaccard**	**Jaro**	**Jaro-Winkler**
Different strings (FN)	**6**	**0.03**	**0.45**	**0.55**	**0.55**
Identical strings (FP)	**3**	**1.00**	**1.00**	**1.00**	**1.00**
Similar Semantics (PP)	**32**	**0.71**	**0.72**	**0.63**	**0.70**
- Unnecessary (extra) characters	7	0.8401	0.8820	0.8714	0.8784
- Common parts (words)	6	0.7122	0.7280	0.6375	0.7043
- Typos	6	0.7797	0.8637	0.8863	0.9220
- Different delimiters	6	0.7860	0.8473	0.9125	0.9442
- Different endings	7	0.8911	0.9135	0.9410	0.9590
Different Semantics (PN)	**18**	**0.89**	**0.89**	**0.89**	**0.91**
- Common parts (words)	11	0.4336	0.5221	0.6161	0.6408
- Very few character differences	7	0.8826	0.8845	0.8914	0.9059
Total:	**59**				

Term similarity thresholds have to be chosen such that full and partial negatives are regarded as not similar, but full and partial positives are regarded as similar. Hence, for the case of partial positives, the thresholds have to be chosen as minimal of all the case categories, and for the partial negatives – as the maximal of all the case categories. The values of case thresholds are shown bolded in Table 1 and provide us with the margins for relevant threshold intervals in our experiments. These intervals have been evenly split in four points as presented in Table 2. The requirements for partial positives and negatives unfortunately contradict to each other. For example, if a threshold is chosen to filter out partial negatives, also some of the partial positives will be filtered out. Therefore, subsuming that partial negatives are rare, it has been decided to use the thresholds for partial positives.

Table 2: Term similarity thresholds chosen for experimental evaluation

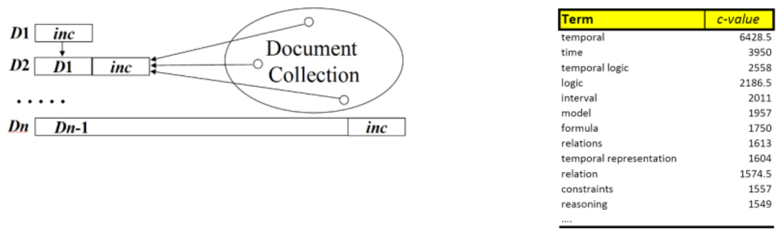
	Term Similarity Thresholds			
	Min	*Ave-1*	*Ave-2*	*Max*
Sørensen-Dice	0.71	0.76	0.83	0.89
Jaccard	0.72	0.77	0.83	0.89
Jaro	0.63	0.72	0.80	0.89
Jaro-Winkler	0.70	0.77	0.84	0.91

4 OntoElect and the Refinement of the THD Algorithm

OntoElect, as a methodology, seeks for maximizing the fitness of the developed ontology regarding what the domain knowledge stakeholders think about the domain. Fitness is measured as the stakeholders' "votes" – a measure that allows assessing the stakeholders' commitment to the ontology under development – reflecting how well their sentiment about the requirements is met. The more votes are collected – the higher the commitment is expected to be. If a critical mass of votes is acquired (say 50%+1, which is a simple majority vote), the ontology is considered to satisfactorily meet the requirements.

Unfortunately, direct acquisition of requirements from domain experts is not very realistic as they are expensive and not really willing to do the work falling out of their core activity. So, we focus on the indirect collection of the stakeholders' votes by extracting these from high quality and reasonably high impact documents authored by the stakeholders.

An important feature to be ensured for knowledge extraction from text collections is that the dataset needs to be representative to cover the opinions of the domain knowledge stakeholders satisfactorily fully. OntoElect suggests a method to measure the terminological completeness of the document collection by analyzing the *saturation* of terminological footprints of the incremental slices of the document collection [1]. The full texts of the documents from a retrospective collection are grouped in datasets in the order of their timestamps. As pictured in Fig. 1a, the first dataset *D*1 contains the first portion (*inc*) of documents. The second dataset *D*2 contains the first dataset *D*1 plus the second incremental slice (*inc*) of documents. Finally, the last dataset *Dn* contains all the documents from the collection.



(a) (b)

Fig. 1: (a) Incrementally enlarged datasets in OntoElect; (b) an example of a bag of terms extracted by UPM Term Extractor [30].

At the next step of the OntoElect workflow the bags of multi-word terms *B*1, *B*2, …, *Bn* are extracted from the datasets *D*1, *D*2, …, *Dn*, using UPM Term Extractor software [30], together with their *significance* (*c-value*) scores. Please see an example of an extracted bag of terms extracted in Fig. 1b.

At the subsequent step, every extracted bag of terms *Bi*, *i* = 1, …, *n* is processed as follows:

- **Normalized scores** are computed for each individual term: *n-score* = *c-value* / max(*c-value*)
- **Individual term significance threshold** (*eps*) is computed to cut off those terms that are not within the majority vote. The sum of *n-scores* having values above *eps* form the majority vote if this sum is higher that ½ of the sum of all *n-scores*.

- The **cut-off** at *n-score* < *eps* is done
- The result is saved in *Ti*

After this step only significant terms, whose *n-scores* represent the majority vote, are retained in the bags of terms. *Ti* are then evaluated for saturation by measuring pair-wise terminological difference between the subsequent bags *Ti* and *Ti*+1, *i* = 0, …, *n*-1. So far it has been done by applying the baseline THD algorithm[4] [1] presented in Fig. 2.

```
Algorithm THD. Compute Terminological Difference between Bags of Terms
Input:
 Ti, Ti+1 - the bags of terms with grouped similar terms.
      Each term Ti.term is accompanied with its T.n-score.
      Ti, Ti+1 are sorted in the descending order of T.n-score.
 M -  the name of the string similarity measure function to compare terms
 th - the value of the term similarity threshold from within [0,1]
Output: thd(Ti+1, Ti), thdr(Ti+1, Ti)
1.  sum := 0
2.  thd := 0
3.  for k := 1, |Ti+1|
4.    sum :=  sum + Ti+1.n-score[k]
5.    found : = .F.
6.    for m := 1, |Ti|
7.        if (Ti+1.term[k] = Ti.term[m])  if (M(Ti+1.term[k], Ti.term[m], th))
8.            then
9.              thd += |Ti+1.n-score[k] - Ti.n-score[m]|
10.             found := .T.
11.    end for
12.    if (found = .F.) then thd += Ti+1.n-score[k]
13. end for
14. thdr := thd  / sum
```

Fig. 2: THD algorithm [1] for measuring terminological difference in a pair of bags of terms. It uses string equalities for comparing terms and therefore needs to be refined as outlined by the rounded rectangles. The refined THD has two more input parameters (*M* and *th*) and uses *M* for comparing terms (line 7) instead of checking the equality of character strings.

In fact, THD accumulates, in the *thd* value for the bag *Ti*+1, the *n-score* differences if there were the same terms in *Ti* and *Ti*+1. If there was no the same term in *Ti*, it adds the *n-score* of the orphan to the *thd* value of *Ti*+1. After *thd* has been computed, the relative terminological difference *thdr* receives its value as *thd* divided by the sum of *n-scores* in *Ti*+1.

Absolute (*thd*) and relative (*thdr*) terminological differences are computed for further assessing if *Ti*+1 differs from *Ti* more than the individual term significance threshold *eps*. If not, it implies that adding an increment of documents to *Di* for producing *Di*+1 did not contribute any noticeable amount of new terminology. So, the subset *Di*+1 of the overall document collection may have become terminologically saturated. However, to obtain more confidence about the saturation, OntoElect suggests that some

[4] The baseline THD algorithm is implemented in Python and is publicly available at https://github.com/bwtgroup/SSRTDC-modules/tree/master/THD

more subsequent pairs of *Ti* and *Ti*+1 are evaluated. If stable saturation is observed, then the process of looking for a minimal saturated sub-collection could be stopped.

Our task was to modify the THD algorithm in a way to allow finding not exactly the same but sufficiently similar terms by applying string similarity measures with appropriate thresholds – as explained in the previous Section 3. For that, the preparatory similar term grouping step has been introduced to avoid duplicate similarity detection.

For each of the compared bags of terms *Ti* and *Ti*+1 the similar term grouping (STG) algorithm is applied at this preparatory step – see Fig. 3.

```
Algorithm STG. Group similar terms in the bag of terms
Input:
 T  – a bag of terms. Each term T.term is accompanied with its
      T.n-score. T is sorted in the descending order of T.n-score.
 M – the name of the string similarity measure function to compare
     terms
 th – the value of the term similarity threshold from within [0,1]
Output: T with grouped similar terms
sum := 0
for k = 1,|T|
  term :=  T.term[k]
  n-score := T.n-score[k]
  count := 1
  for m = k+1,|T|
       if M(term, T.term[m], th)
          then
            n-score += T.n-score[m]
            count += 1
            remove(T[m])
  end for
  T.n-score[k] := n-score / count
end for
```

Fig. 3: Similar Term Grouping (STG) algorithm

After term grouping is accomplished for both bags of terms, the refined THD algorithm (Fig 2 – rounded rectangles) is performed to compute the terminological difference between *Ti* and *Ti*+1.

5 Cross-Evaluation

This section reports on our evaluation of the refined THD algorithm against the baseline THD [1]. This evaluation is done following the workflow of OntoElect Requirements Elicitation Phase [31] and using the TIME document collection.

5.1 Set-up of the Experiment

The objective of our experiment was to find out if using the refined THD algorithm yields quicker and smoother terminological saturation compared to the use of the baseline THD algorithm. We were also looking at finding out which string similarity measure best fits for measuring terminological saturation.

For making the results comparable, the same datasets created from the TIME document collection – as described in Section 5.2 – has been fed into both the refined and baseline THD algorithms. We applied:

(i) The refined THD – sixteen times – one per individual string similarity measure *M* (Section 3) and per individual term similarity threshold *th* (Table 3); and

(ii) The baseline THD – one time

The values of: (i) the No of retained terns; (ii) absolute terminological difference (*thd*); and (iii) the time taken to perform term grouping by the STG algorithm (*sec*); were measured.

Finally, to verify if the refined THD is correct, we checked if it returns the same results as the baseline THD when the term similarity threshold is set to 1.0.

All the computations have been run on a Windows 10 64-bit PC with: Intel® Core™ 2 Duo CPU, E7400 @ 2.80 GHz; 4.0 Gb on-board memory.

5.2 Experimental Data

TIME document collection contains the full text papers of the proceedings of the TIME Symposia series[5]. The domain of the collection is Time Representation and Reasoning. The publisher of these papers is IEEE. It contains all the papers published in the TIME symposia proceedings between 1994 and 2013, which are 437 full text documents. These papers have been processed manually, including their conversion to plain texts and cleaning of these texts. So, the resulting datasets were not very noisy. We have chosen the increment for generating the datasets to be 20 papers. So, based on the available texts, we have generated 22 incrementally enlarged datasets *D*1, *D*2, …, *D*22[6] using our Dataset Generator[7]. The **chronological** order of adding documents has been used.

5.3 Results and Discussion

The results of our measurements of terminological saturation (*thd*) are pictured in a diagrammatic form in Fig. 4. The diagrams showing the time spent by the STG algorithm for detecting and grouping similar terms, based on the chosen term similarity thresholds are in Fig. 6. The diagrams in Fig. 4 and 6 have been built using the values

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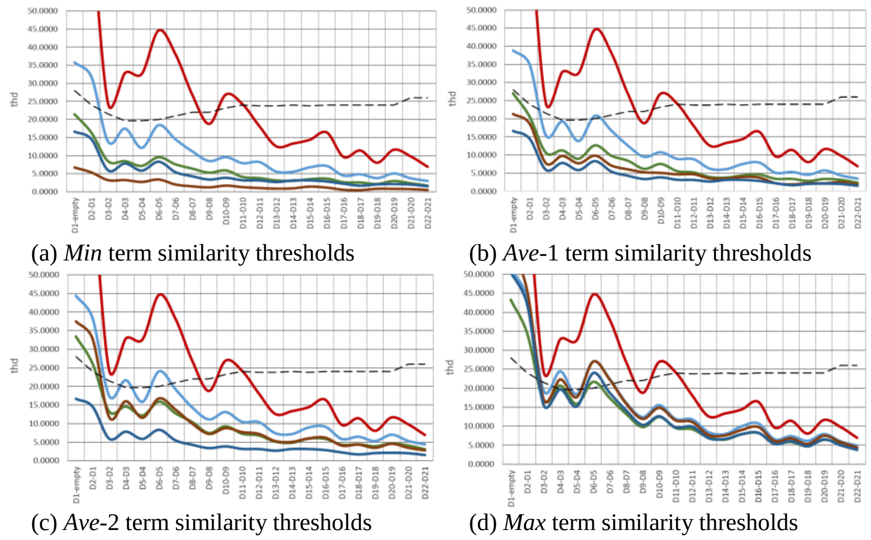
5 http://time.di.unimi.it/TIME_Home.html

6 The **TIME** collection in plain text and the datasets generated of these texts are available at: https://www.dropbox.com/sh/64pbodb2dmpndcy/AAAzVW7aEpgW-JrXHaCEqg2Sa/TIME?dl=0

7 The dataset generator is available at: https://github.com/bwtgroup/SSRTDC-PDF2TXT

of the measurements from the four tables – one per term similarity threshold point (*Min*, *Ave*-1, *Ave*-2, and *Max*)[8].

Saturation (*thd*) measurements reveal that the refined THD algorithm detected terminological saturation faster than the baseline THD algorithm – no matter what was the chosen term similarity measure (*M*) or the similarity threshold (*th*). If the results for different measures are compared, then it may be noted that the respective saturation curves behave differently, depending on the similarity threshold point.



(a) *Min* term similarity thresholds (b) *Ave*-1 term similarity thresholds

(c) *Ave*-2 term similarity thresholds (d) *Max* term similarity thresholds

Legend: Sørencen-Dice Jaccard Jaro Jaro-Winkler Baseline eps

Fig. 4: Terminological saturation measurements grouped in four different term similarity threshold (*th*) points: (a) *Min*; (b) *Ave*-1; (c) *Ave*-2; and (d) *Max*. The legend shows the colors for different string similarity measures.

Overall, as it could be seen in Fig 4 (a) – (d), the use of the Sørensen-Dice measure demonstrated the least volatile behavior along the term similarity threshold points. This measure resulted in making the refined THD algorithm to detect saturation slower than the three other measures for *Min*, *Ave*-1, and *Ave*-2. For Max, it was as fast as Jaro and slightly slower than Jaccard and Jaro-Winker.

One more observation was that, integrally, all the implemented term similarity measures coped well with retaining important terms. These are indicated by terminology contribution peaks in the diagrams (a)-(d) of Fig. 4. It is well seen in Fig. 4(d), for the *Max* threshold point, that all the string similarity method curves follow the shape of the baseline THD curve quite closely. Hence, they have the peaks exactly in the same *thd* measurement points where the baseline has, pointing at more new significant terms.

8 The tables are not presented in the paper due to the page limit, though are publicly available at: https://github.com/EvaZsu/OntoElect. File names are Results-Alltogether-{min, ave, ave2, max}-th.xlsx

At Min, Ave-1, and Ave-2, however, the method that have been most sensitive to terminology peaks, was Sørensen-Dice. This sensitivity is also confirmed by Fig. 5.

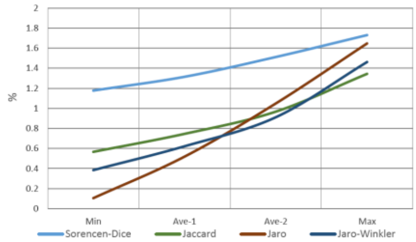
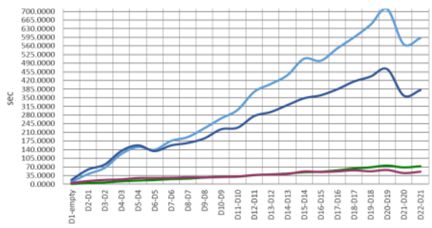
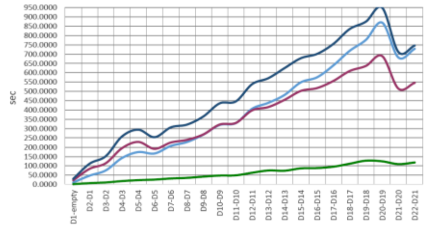


Fig. 5: Proportions of retained to all extracted terms for different term similarity measures

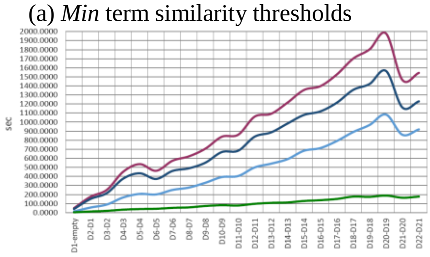
Fig. 5 pictures the proportions of the retained to all extracted terms computed at different term similarity threshold points. It is clear from Fig. 5 that Sørensen-Dice retains the biggest number of terms at all used term similarity thresholds.



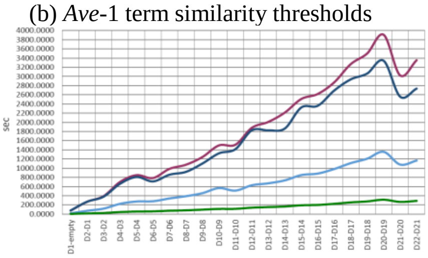
(a) *Min* term similarity thresholds



(b) *Ave*-1 term similarity thresholds



(c) *Ave*-2 term similarity thresholds



(d) *Max* term similarity thresholds

Legend: Sørencen-Dice Jaccard Jaro Jaro-Winkler

Fig. 6: Time (sec) spent for finding similar terms, grouped similarly to Fig. 4

Finally, it has to be noted that the introduction of string similarity measures in the computation of terminological difference (THD algorithm) increases the computational complexity of the algorithm quite substantially. Fig. 6 pictures the times (in seconds) taken by the pre-processor STG algorithm. As it could be noticed in Fig. 6(a)-(d), the times grow with the value of the term similarity threshold (*th*) and reach thousands of seconds for *Max* threshold values. It is interesting to notice that Sørensen-Dice and Jaccard are substantially more stable to the increase of *th* than Jaro and Jaro-Winkler. Sørensen-Dice takes, however, roughly an order of magnitude more time than Jaccard.

From the other hand, Jaccard was not very sensitive to terminological peaks and retained significantly less terms than Sørensen-Dice.

To sum up, the findings are put in Table 3 to rank the evaluated string similarity measures on a scale 1 (the best) to 5 (the worst).

Table 3: The ranking of the evaluated string similarity measures

Evaluation aspect	**Rank (1-5)**				
	Baseline THD	**Sørensen-Dice**	**Jaccard**	**Jaro**	**Jaro-Winkler**
Faster detection of terminological saturation	5	3	1	4	2
More significant terms retained	1	2	3	5	4
Less time taken	1	3	2	5	4
Total:	**7(2)**	**8(3)**	**6(1)**	**14(5)**	**10(4)**

Probably surprisingly, Jaccard, which is the most lightweight string similarity measure (Fig. 6), demonstrated the best performance among the rest, including the baseline THD. As it was well balanced on all evaluation aspects. This balance was also good in the case of Sørensen-Dice. However, Sørensen-Dice lost to Jaccard and baseline THD as it took too much time for term grouping. Jaro and Jaro-Winkler were clear negative outliers. Therefore, at an expense of a slightly higher execution time, the THD refined by Jaccard string similarity measure is the preferred choice for measuring terminological saturation in OntoElect.

6 Conclusions and Future Work

In this paper, we investigated if a simple string equivalence measure used in the baseline THD algorithm may be outperformed if a proper string similarity measure is used instead. For finding this out, we: (i) have chosen the four candidate measures from the broader variety of the available, based on the specifics of term comparison; (ii) developed the test set of specific term pairs to decide about term similarity thresholds for the chosen measures; (iii) implemented these measures, the algorithm for similar terms grouping (STG), and the refinement of the baseline THD algorithm; (iv) cross-evaluated the refined THD algorithm against the baseline, and also all individual measures against each other; (v) gave our recommendation about the use of the refined THD algorithm with Jaccard measure which demonstrated the most balanced performance in our experiments.

For the experiments we used the datasets generated, using our instrumental software suite, from the TIME document collection. This collection contains real scientific papers acquired from the proceedings series of the Time Representation and Reasoning Symposia.

Our future work is planned based on the results of the presented experiments and some additional observations we made. Firstly, we would like to explore the ways to improve the performance of the Sørensen-Dice measure implementation as its higher computational complexity is the only flaw against the Jaccard measure implementation. Secondly, we are interested in finding out if a similar term grouping algorithm, using a sensitive similarity measure, like Sørensen-Dice, would be plausible for grouping features while building feature taxonomies. This task is on the agenda for the second (Conceptualization) phase of OntoElect [32]. Thirdly, we are keen to check if the evaluation results on the other document collections will be similar to that presented in this paper. To find this out we plan to repeat the same cross-evaluation experiments but on the datasets generated from DMKD and DAC collections [16].

Acknowledgements

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Estimation of the Production Potential of Ukraine's Regions using Kohonen Neural Network

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Abstract. The problem of estimating the level of production potential for different time periods is investigated. It is proposed to apply an integrated approach to the analysis of the regional indicators complex that characterize the level of production potential. At the first stage, the normalization of indicators is carried out taking into account their economic content. The next stage is the calculation of integral indicators in three different approaches. At the last stage, the clustering of the regions by the level of production potential is carried out using Kohonen neural network. Application the Kohonen map with the database clustering simultaneously allows to project multidimensional data into two-dimensional space and analyze the resulting cluster system. The choice of the clusters number is based on the cluster indicator calculation, in contrast to the traditional statistical approach, based on the Störges formula using. It allows to improve the clustering results by selecting the optimal number of partition groups. The convenient form of visualization of the clustering results enables to localize the features and make appropriate adjustments to the rating list, based on expert judgements.

Keywords: production potential, Kohonen neural network, level of region development, integral estimation, competitiveness of regions.

1 Introduction

The current development of Ukraine is characterized by interregional socio-economy disparity, an increased level of disproportion in the development of individual regions and the emergence of differences in the sectoral structure of economic systems of different regions. The difference in the economic development of the country as a whole leads to the domination of some regional systems over others. Therefore, an important stage in the analysis of the development of the country as a whole, is the assessment of each of the regions.

This topic is relevant and open to new research because it is difficult to identify a single set of indicators that characterize the state of regional development fully. There is a problem of calculating the integral indicator the estimation and ranking of regions by level of development.

The purpose of the paper is application of integrated approach to assessing the level of development of regions of Ukraine in terms of production potential based on the construction of integral indicators and clustering by methods of neural networks.

2 Analysis of Recent Research

The problem of disproportionate regional development is one of the most important and actual that must be solved not in Ukraine only but also in the whole world. For effective public administration it is necessary to assess the level of development of regions, to identify regions with different levels of development. Therefore, a large number of scientific papers are devoted to this sphere. A lot of scientific works are devoted to the development and research of the problem of assessing the level of development of regions, their competitiveness. The theoretical basis for estimation the development of regions is considered in [1-5]. Different approaches and methods of diagnostics of regional development are presented in works [6-18]. Depending on the goals and objectives of the study, both statistical indicators and expert assessments are used, methods of integrated indicators construction are used [7, 10, 14], and develop scenario models for the development of regions [16].

Thus, (Pike, Rodriguez-Pose, Tomaney) [1] consider purposes, principles and values of regional development, and integrated approaches to local and regional development throughout the world. The approach provides a theoretically informed, critical analysis of contemporary local and regional development in an international and multi-disciplinary context, grounded in concrete empirical analysis.

Rivza, Azena, Sunina [2] study the impact of regional development on the development of enterprise environment. In order to implement the aim the authors investigated theories of regional development and studied the indicators of environment development in two cities in Latvia.

Ciobanu [3] considers regional development that is currently being discussed at national or European level, the effects of reorganization, the greatest achievement concerning economic and social cohesion, mitigating intra- and inter regional differences.

Korent, Vukovic, Brcic [8] apply correlation and dynamic panel data analysis on the set of data from Croatian counties with levels and relative changes of the selected regional growth indicators.

Meyer, De Johng, Meyer [11] construct a composite regional development index that successfully measures all the dimensions of development in a quantitative manner. The index was designed to be able to assess regions on a national, regional and local level. The hypothesised index consisted of four dimensions (demographic, social, labour and economic) that were constructed using 17 indicators.

Di Pietro et al. [12] study the influence of regional institutional environment, measured as regional development, on capital structure of small and medium-sized enterprises (SMEs).

Bachtler and Begg [13] highlights innovation, human capital and effective institutions as three crucial dimensions of future regional policy.

Li and Xu [15] use multi-index comprehensive measurement to calculate the composite index of the level of economic development of each evaluation unit for counties in Taiwan.

Kohonen neural networks are used for solving research problems in different fields of knowledge [19-36]. Lototskiy [19] considered the method of images fractal compression. The algorithm of clustering by means of artificial Kohonen neural networks was constructed.

Bacao, Lobo, Painho [20] review different initialization procedures, and propose Kohonen's Self-Organizing Maps as the most convenient method, given the proper training parameters.

Mingoti and Lima [21] present a comparison among some nonhierarchical and hierarchical clustering algorithms including SOM (Self-Organization Map) neural network and Fuzzy c-means methods.

Fayos and Fayos [22] consider time series of Circulation Weather Type, including daily averaged wind direction and vorticity, that are self-classified by similarity using Kohonen Neural Networks.

Dekker [23] presents a self-organizing Kohonen neural network for quantizing colour graphics images. The network is compared with existing algorithmic methods for colour quantization. It is shown experimentally that, by adjusting a quality factor, the network can produce images of much greater quality with longer running times, or slightly better quality with shorter running times than the existing methods

Nizam [24] presents a new cluster bus technique using Kohonen neural network for the purpose of forming bus clusters in power systems from the voltage stability viewpoint. This cluster formation will simplify voltage control in power system.

Singh et al. [25] propose and analyze Kohonen neural network tracking control of nonlinear system. Proposed adaptive Kohonen neural network are used to recognize class of nonlinear discrete-time systems.

3 Research Methods

The economic situation of any country is largely determined by the level of development of industry and agriculture. So, one of the most important groups of indicators of socio-economic development of the regions is exactly the production potential.

Production potential is the maximum possible volume of output that the economy is able to produce with the full involvement of all available resources in the process of social production [6]. The assessment of the production potential of the region is based on the analysis of its components: industrial, agricultural and investment potential. In turn, the characteristic of the industrial potential of the region is based on the research of the following indicators: the volume of industrial products sold (works, services), the share of the region; volume of sold industrial products (works, services) and volume of sold industrial products (works, services) per person. Regarding agricultural potential, its analysis is carried out on such indicators as gross crop production and gross livestock production. The investment potential in this research is characterized by an indicator of capital investment.

The construction of the integral index for assessing the production potential of the regions is carried out according to the following three approaches.

The first methodology is an integrated assessment of the competitiveness of regions, proposed in [7]. It has a hierarchical structure, which consists of three types of indices:

1) general integral index of the benefits of the region;
2) group integral indices of various aspects of the region's life;
3) partial integral indices characterizing the advantages of the region.

The proposed technology for calculating the regional benefits index implies the formation of databases, that is, the formation of a matrix of output data (X), determination of indicators of stimulant and distimulant, as well as their normalization.

Indicators-stimulant are calculated by the formula:

$$k = \frac{X_{ij}}{X_{ij\max}}. \tag{1}$$

Indicators-distimulant:

$$k = \frac{X_{ij\min}}{X_{ij}}, \tag{2}$$

where $X_{ij\max}$ - the maximum value of the indicator j in the region i; - the minimum value of indicator j in the region i.

Calculation of the consolidated integral index of investment advantages of the region is carried out on the basis of the formula of the average geometric group integral indexes, which characterize its main aspects:

$$K_w = \sqrt[r]{K_{part.1} \cdot K_{part.2} \cdot \ldots \cdot K_{part.r}}, \tag{3}$$

where $K_{part} = \sqrt[n]{k_1 \cdot k_2 \cdot \ldots \cdot k_n}$, n is the number of indicators included in a certain group indicator.

The second technique [14] also uses a hierarchical analysis scheme. At the stage of calculation of the group indicator from the obtained normalized indicators it is suggested to use the formula:

$$K_{part} = \sqrt[n]{\prod(1+k_n)} - 1. \tag{4}$$

Next, the radial diagram of regional competitiveness is being constructed according to the group indicators. The total area of the sectors of the chart will determine the integral index of the region's competitiveness and will be calculated according to the following formula:

$$I_i = \frac{1}{2} \sin \frac{360}{r} \sum_{r=1} K_{part_{ir}} K_{part_{ir+1}}, \tag{5}$$

where I_i - the integral index of the region i; r - the number of groups of indicators or the number of calculated integral indicators for each of the groups of indicators.

The third method [37] for the valuation of indicators offers the following formulas: for indicator-stimulants:

$$k_{ij} = \frac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}}, \tag{6}$$

for indicators-distimulants:

$$k_{ij} = \frac{X_{\max} - X_{ij}}{X_{\max} - X_{\min}}, \tag{7}$$

where X_{ij} - the value of the indicator in the region i; $X_{\max}$ - the maximum value of the indicator j for all regions; $X_{\min}$ - the minimum value of indicator j for all regions.

Then the value of the factor weight is calculated. This procedure consists of three consecutive steps: calculation of the product of the factor load $|f|_k$ and the share of the total dispersion d_k that it explains; calculation of the sum of the received products of all factors and calculation of each factor contribution to the specified amount, that is, the actual weight of the factor in the general model:

$$W_k = \frac{q_k}{\sum_{k=1} q_k}. \tag{8}$$

The next stage is the calculation of aggregate indicators I_{jl}, characterizing certain aspects of economic development and the calculation of the integral index of economic development by the following formulas:

$$I_{jl} = \sum_{i=1}^{n} k_{ij} W_i, \tag{9}$$

$$I_{ej} = \sum_{l=1}^{r} I_{jl} W_l, \tag{10}$$

where k_{ij} is the normalized indicator i of the economic development block l in the region j; W_i is the weight of indicator i in the aggregate indicator of the block l; n is the number of indicators for economic development estimation; W_l is the weight of the block l in the integral index of economic development.

In [7, 10, 14] for clusterization of regions by integral indicators, it is proposed to determine the number of groups by the Störges formula:

$$N = 1 + 3{,}322 \lg m, \tag{11}$$

where m is the number of regions under consideration.

At the same time grouping is calculated by the formula:

$$h = \frac{I_{\max} - I_{\min}}{N}, \tag{12}$$

where $I_{\max}$ is the maximum of integral indicators; $I_{\min}$ is the minimum of integral indicators.

A powerful alternative clustering method is the use of Kohonen's neural networks (Kohonen self-organizing maps – SOM) [20-36]. It is the most well-known unsupervised neural network approach to clustering [26]. Its advantage over traditional clustering technique is improved visualization capabilities. SOMs find a mapping from high dimensional input space into the feature space of reduced dimension and make possible visualization in reduced dimensionality.

On the initial stage of SOM learning algorithm we should set the weights to small random values, the initial neighborhood size $N_m(0)$ and the values of parameter function $\alpha(t)$ and $\sigma^2(t)$ (between 0 and 1). The steps of algorithms are as follows [26].

STEP 1: Randomly select an input pattern x to present to the SOM through the input layer.

STEP 2: Calculate the similarity (distance) between this input and the weights of each neuron j:

$$d_j = \left\| x - w_j \right\| = \sqrt{\sum_{i=1}^{n} \left(x_i - w_{ji} \right)^2}. \tag{13}$$

STEP 3: Select the neuron with minimum distance as the winner m

STEP 4: Update the weights connecting the input layer to the winning neuron and its neighboring neurons according to the learning rule:

$$w_{ji}(t+1) = w_{ji}(t) + c\left[x_i - w_{ji}(t) \right], \tag{14}$$

where $c = \alpha(t)\exp\left(-\left\| r_i - r_m \right\| / \sigma^2(t) \right)$ for all neuron j in $N_m(t)$

STEP 5: Continue from STEP1 for Ω epochs; the decreased neighborhood size, $\alpha(t)$ and $\sigma^2(t)$: Repeat until weights have stabilized.

The Ward clustering in general is hierarchical agglomerative clustering algorithm [27, 28]. On the initial stage of clustering each node is defined as a cluster itself. At each next stage two clusters with minimum distance between them are combined in one new cluster. This distance is called Ward distance and defined as follows:

$$d_{rs} = \frac{n_r n_s}{(n_r + n_s)} \left\| \bar{x}_r - \bar{x}_s \right\|^2 , \tag{15}$$

where r and s denote two specific clusters, n_r and n_s are the number of data points in the two clusters, and $\bar{x}_r$ and $\bar{x}_s$ denote the centers of gravity of the clusters; $\|.\|$ is the Euclidean norm. Starting from the full distance matrix (lower triangle matrix as the distance measure is commutative), at every step a row and a column is stripped (and a different row and column is updated) until the matrix is completely cleared and only one cluster remains. The mean and cardinality of the new cluster built as product of the combining step is as follows:

$$x_r^{(new)} = \frac{n_r \bar{x}_r + n_s \bar{x}_s}{n_r + n_s}, \tag{16}$$

$$n_r^{(new)} = n_r + n_s . \tag{17}$$

The SOM-Ward clustering approach is a two-level clustering approach which combines the standard Ward's algorithm to determine the SOM and clustering results. Ward clustering algorithm as agglomerative hierarchical algorithm have the following steps [29]:

1. Initialize: assign each vector to its own cluster.
2. Compute distances between all clusters.
3. Merge the two clusters that are the closest to each other.
4. Return to step (2) until there is only one cluster left.

As a specialty, the distance matrix is initialized in a manner that takes into account the number of data records matching to the nodes of the map. Nodes with many matching data records are weighted stronger than nodes with fewer matching records. As distance measure we have to use a modified Ward distance

$$d_{rs} = \begin{cases} 0 \quad if \quad n_r = n_s = 0, \\ \dfrac{n_r n_s}{n_r + n_s} \left\| \bar{x}_r - \bar{x}_s \right\|^2 \quad otherwise. \end{cases} \tag{18}$$

While determining the distance, both the Ward distance and the topological properties of SOM are taken into account. In other words, the distance between two nonassociated clusters is considered as infinite and only the associated clusters are combined. Low SOM-Ward distance value represents a more natural clustering for the map, and high value represents an artificial clustering for the map. By this means, users can select the optimal cluster number in a flexible manner [30].

For the SOM-Ward clustering the distance is redefined as

$$d'_{rs} = \begin{cases} d_{rs} \quad if \ clusters \ r \ and \ s \ are \ adjacent \ in \ the \ SOM, \\ \infty \quad otherwise. \end{cases} \tag{19}$$

The modified SOM-Ward clustering algorithm combines a method of displaying data using self-organizing maps with a classical hierarchical Ward clustering algorithm [31, 32]. This method offers its own clustered indicator, which defines the reasonable number of clusters into which the input sample is broken [33].

4 Research results

The statistical data of 24 regions (excluding Kyiv) for the period 2010-2016 [37] is used for estimation of the productive potential of the regions. Results of ranking of regions by integral indicator of production potential are presented in Table 1. The calculations were carried out according to three methods mentioned above. Method 1 is described by formulas (1) – (3), method 2 – formulas (1), (2), (4), (5) and method 3 – formulas (8) – (10). For the convenience of the user, the methods were implemented in the EXCEL environment. The clustering algorithm and the variance analysis are implemented in EXCEL and SOMine. The ratings that adduced for comparison are based on the results of the regions in 2010, 2013 and 2016.

Table 1. Places of regions of Ukraine in the ranking on the level of production potential

Regions	The first method			The second method			The third method		
	2010	2013	2016	2010	2013	2016	2010	2013	2016
Vinnytsia	11	9	7	10	8	8	12	11	9
Volyn	21	20	18	22	19	18	21	20	18
Dnipropetrovsk	1	1	1	1	2	1	2	2	1
Donetsk	2	2	5	2	1	6	1	1	2
Zhytomyr	17	17	15	18	18	17	18	17	15
Zakarpattia	23	23	23	23	23	23	22	23	23
Zaporizhia	5	7	6	4	10	7	3	4	4
Ivano-Frankivsk	13	14	16	13	14	15	13	14	14
Kiev	3	3	2	3	3	2	6	5	5
Kirovohrad	19	16	14	15	15	13	19	16	16
Luhansk	7	6	22	9	6	22	4	6	21
Lviv	9	8	8	8	9	5	9	8	7
Mykolaiv	12	12	11	12	12	11	11	12	10
Odessa	8	10	10	7	7	9	8	10	11
Poltava	4	4	4	5	4	4	5	3	3
Rivne	18	19	20	21	21	21	17	19	17
Sumy	15	15	13	16	16	14	14	13	13
Ternopil	22	22	21	20	20	20	23	22	22
Kharkiv	6	5	3	6	5	3	7	7	6
Kherson	20	21	19	19	22	19	20	21	20
Khmelnytskyi	14	13	12	14	13	12	15	15	12
Cherkasy	10	11	9	11	11	10	10	9	8

Chernivtsi	24	24	24	24	24	24	24	24	24
Chernihiv	16	18	17	17	17	16	16	18	19

From Table 1 it follows that the use of different techniques gives close results for leaders and outsiders ranking. Donetsk and Dnipropetrovsk regions occupied the first and second places in the level of production potential in 2010 and 2013, and Dnipropetrovsk region is also the leader in 2016. As for the Donetsk region, it dropped to 5-6 places by the results of the use of the first and second methodology. Donetsk region remained in second place for the third method. But according to all approaches, the value of productive potential level of this region has significantly decreased compared with 2013 and 2010. This is not surprising given the situation in the east of the country. The worst indicators for all years showed the Chernivtsi region (24th place) and the Zakarpattia region (23). Over the researched period, the following regions improved their results: Vinnytsia, Kiev, Lviv, Poltava, Mykolaiv, Kharkiv, Cherkasy. As well as minor but positive changes have taken place in the Volyn, Zhytomyr, Kirovohrad, Sumy and Khmelnytskyi regions.

There were 5 clusters allocated for 24 regions using the Störges formula. In Table 2 shows the clustering of regions of Ukraine by the level of production potential in 2016 for each of the three methods.

It should be noted that for regions with average values of integral indicators, calculated according to different approaches, there are significant differences in the distribution of regions by clusters and their mutual ordering. The Kohonen neural network was used to verify the results and identify stable homogeneous groups of regions.

Table 2. Clusterization of the regions of Ukraine by the level of production potential in 2016

Level of competitive	The first method	The second method	The third method
MAXIMUM	Dnipropetrovsk (1)	Dnipropetrovsk (1)	Dnipropetrovsk (1)
HIGH	Kiev (2)	Kiev (2)	-
MODERATE	Kharkiv (3) Poltava (4) Donetsk (5)	-	Donetsk (2) Poltava (3) Zaporizhia (4) Kiev (5) Kharkiv (6)
MEDIUM	Zaporizhia (6) Vinnytsia (7) Lviv (8) Cherkasy (9) Odessa (10) Mykolaiv (11) Khmelnytskyi (12)	Kharkiv (3) Poltava (4) Lviv (5)	Lviv (7) Cherkasy (8) Vinnytsia (9) Mykolaiv (10)

LOW	Sumy (13) Kirovohrad (14) Zhytomyr (15) Ivano-Frankivsk (16) Chernihiv (17) Volyn (18) Kherson (19) Rivne (20) Ternopil (21) Luhansk (22) Zakarpattia (23) Chernivtsi (24)	Donetsk (6) Zaporizhia (7) Vinnytsia (8) Odessa (9) Cherkasy (10) Mykolaiv (11) Khmelnytskyi (12) Kirovohrad (13) Sumy (14) Ivano-Frankivsk (15) Chernihiv (16) Zhytomyr (17) Volyn (18) Kherson (19) Ternopil (20) Rivne (21) Luhansk (22) Zakarpattia (23) Chernivtsi (24)	Odessa (11) Khmelnytskyi (12) Sumy (13) Ivano-Frankivsk (14) Zhytomyr (15) Kirovohrad (16) Rivne (17) Volyn (18) Chernihiv (19) Kherson (20) Luhansk (21) Ternopil (22) Zakarpattia (23) Chernivtsi (24)

Calculations were made according to the statistics of 2016. The same indicators as in previous methods were considered. The SOM-Ward method performed clustering of input data and calculated the clustered indicator [34] for each of the possible cluster numbers (see Fig. 1).

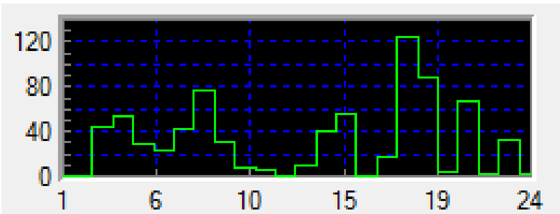

Fig. 1. Cluster indicator diagram

The horizontal axis of the diagram indicates the number of clusters, the vertical axis shows the indicator value for each cluster system. The diagram can be interpreted as follows: if the indicator value is high for a particular cluster system, then clustering can be considered as "natural" for the constructed map. Accordingly, when the indicator value is low for some cluster system, clustering is "artificial." Consequently, the peaks of the clustered indicator graph represent true clustering.

According to calculations, the largest indicator corresponds to 18 clusters, the next maximum is 8 clusters. But, given that the number of investigated objects is 24, it is expedient to group the regions into the 8 clusters. Fig. 2 shows the division of regions into 8 groups by the level of production potential in 2016. In brackets, under the name of the region, the average place in the ranking is indicated by the results of previous calculations. Note that the regions-leaders tend to the left side of the map, and outsiders tend to the right side of the map. The division of regions into five groups (Fig. 3), which was proposed earlier, is considered in parallel, in order to compare the results. It should be noted that the indicator for such a number of clusters was very low, clustering in five groups is artificial and not entirely correct.

The adequacy of the constructed clusterization models was verified using a dispersion analysis. For each investigated indicator, the intergroup and intragroup components of the variance were calculated and the hypothesis of their significant difference was checked. The results of the calculations confirmed the quality of clustering at the level of significance of 5% (Table 3).

Table 3. Results of the dispersion analysis

Indicator	Intergroup variance	Dispersion inside the cluster	F	p
Gross crop production	1,65	0,21	66,44	0,00009
Gross livestock production	0,74	0,04	151,75	0,00001
Volume of sold industrial products (works, services)	0,53	0,04	107,08	0,00003
Volume of sold industrial products (works, services), share of the region	0,50	0,04	101,75	0,00003
Volume of sold industrial products (works, services) per person	0,15	0,18	7,29	0,01728
Capital investments	0,16	0,22	6,11	0,02551

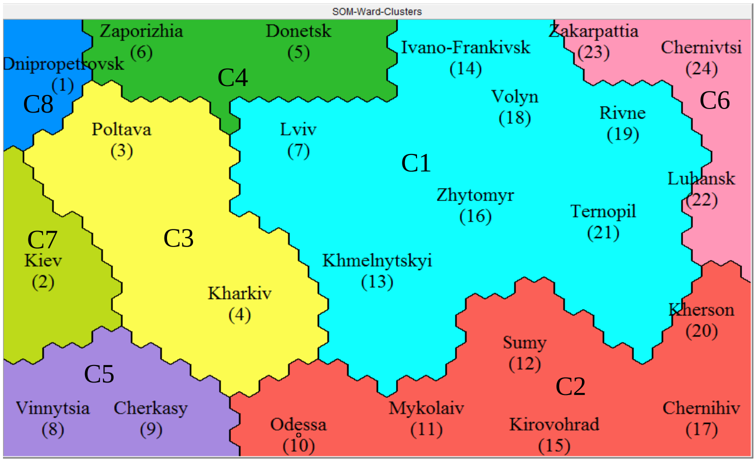

Fig. 2. Distribution of regions into 8 groups by level of productive potential (year 2016).

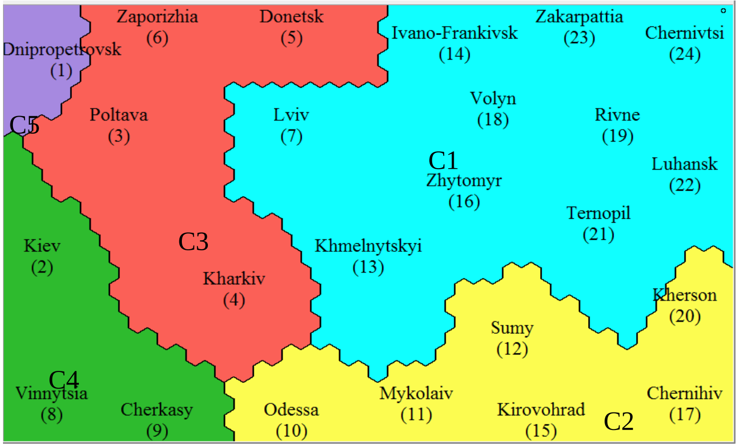

Fig. 3. Distribution of regions into 5 groups by level of productive potential (year 2016).

Fig. 4 presents a profile of contributions of indicators in the formation of 8 clusters (the contributions of indicators are arranged from the bottom up according to their ordering in the performed calculations out and marked with different colors).

The Dnipropetrovsk region is in the first place with the highest value of the integral indicator and is isolated in the C8 cluster. All cluster metrics are at levels above the average significantly. The next cluster (C7) consists of the Kiev region, which has somewhat lower levels of indicators.

Vinnytsia (8) and Cherkasy (9) are in the same cluster (C5), which is characterized by a very high level of gross livestock production and gross crop production. One can note that on Fig. 3 Kiev, Vinnytsia and Cherkasy regions form one of the 5 clusters. However, Kiev region is significantly different from the other two regions by the level of capital investment, therefore, its allocation to a separate cluster is justified.

Poltava (3) and Kharkiv (4) regions from the C3 cluster have the values of indicators that are higher significantly than the average level. Also, the following cluster C4 consists of two regions: Zaporizhia (6) and Donetsk (5) regions. In Fig. 3 all four regions form one cluster. However, the C4 cluster, unlike C3, includes regions whose agricultural production indicators are lower significantly than the average level. Odessa (10), Mykolaiv (11), Sumy (12), Kirovohrad (15), Chernihiv (17) and Kherson (20) form the C2 cluster (Fig. 2) and the C3 cluster (Fig. 3). All indicators of these regions are lower than the average level, except of gross crop production indicator.

The C1 cluster includes Lviv (7), Ivano-Frankivsk (14), Khmelnytskyi (13), Zhytomyr (16), Volyn (18), Rivne (19), Ternopil (21) regions. All indicators of this group of regions are at a level that is significantly lower than the average. The C6 cluster is characterized by the largest deviation in the negative side of all studied indicators and includes the following areas: Luhansk (22), Zakarpattia (23), Chernivtsi (24). Note that in Fig. 3 clusters C1 and C6 have been united into one cluster. Separating the last three regions into a separate group is logical and reasonable.

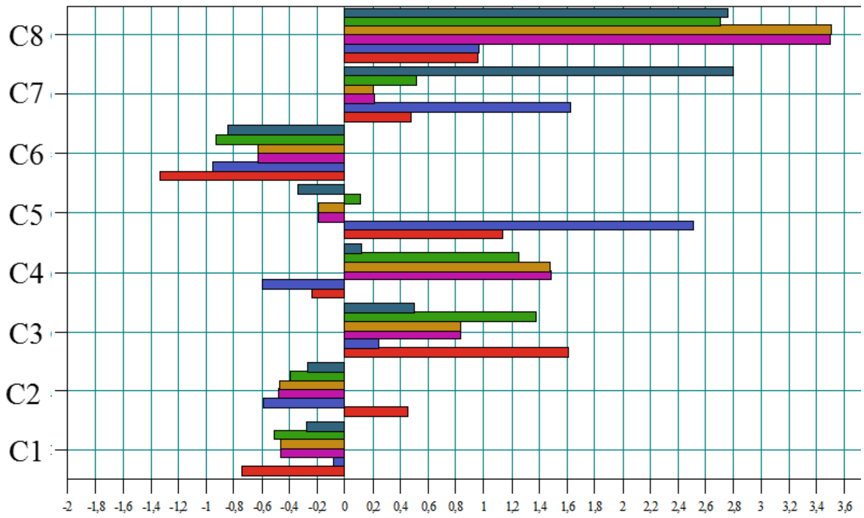

Fig. 4. Profile of contributions to the formation of 8 clusters.

At the next step Kohonen maps are built without taking into account the six regions that have ranked as the leaders. That is done in order to improve the results of conducted clustering and the allocation of stable homogeneous groups. This approach allows to reveal structural features of the aggregate of regions with average values of integral indicators.

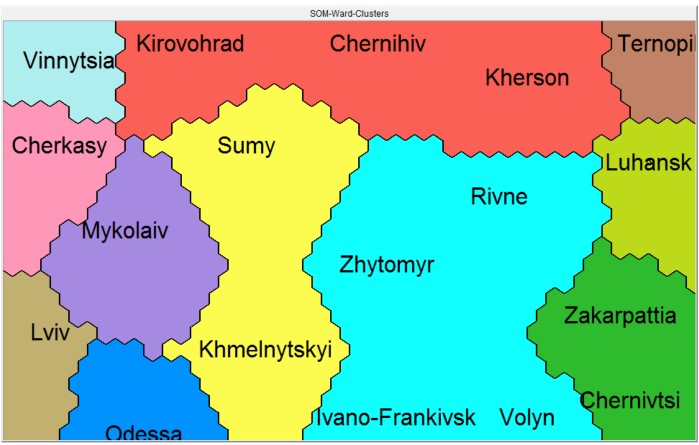

Fig. 5. Distribution of regions into 11 groups by level of productive potential (year 2016)

In Fig. 5 the distribution of regions into 11 clusters is presented and new groups are allocated. The proximity of following regions is detected: Sumy and Khmelnytskyi; Zhytomyr, Rivne, Ivano-Frankivsk, Volyn; Kirovohrad, Chernihiv, Kherson. It should take into account the location of the region on the map, compared with its neighbors, proximity to the leaders or outsiders of the rating.

During clustering using the Kohonen network, it was discovered that distribution into five clusters does not allow to make qualitative grouping and ranking of regions. Note that the rating estimation of the region did not always coincide with the location of the region itself on the map in terms of ratings of the closest neighbors by cluster. Therefore, there are grounds for improvement and modification of the proposed algorithms for determining the competitiveness of regions, taking into account the possibility of the Kohonen neural networks.

Also, it should be noted that the city of Kiev was not included in the list of studied regions. If we take into account the indicators of the city of Kiev, this will greatly complicate the processes of ranking and clustering, because most regions have low rates compared to the city of Kiev. Therefore it is expedient to compare the indicators of the city of Kiev with the indicators of areas with the highest level of production potential.

5 Conclusion

By means of various methodological approaches, the level of Ukraine's regions production potential was assessed by taking into account the industrial, agricultural and investment potential of the regions in different time moments. Further clustering of the studied regions was accomplished with the Kohonen neural maps. Using Kohonen maps with simultaneous database clustering made it possible to design multidimensional data in two-dimensional space, visually analyze the obtained cluster system and improve the results of clustering by choosing the optimal number of distribution groups. The number of clusters calculated according to the statistical approach was artificial. The construction of the Kohonen map allowed to improve the situation and select a reasonable number of clusters.

Note that the rating estimation of the region did not always coincide with the location of the region itself on the map in terms of ratings of the closest neighbors by cluster. This is due to the fact that the whole database and the nonlinear model of clustering were used in constructing the map and conducting clustering, in contrast to the methods for calculating total integral indicators and even grouping. A convenient form of visualization of the results of clustering allows to localize the features and make appropriate adjustments to the rating lists based on expert considerations.

During the research period, the growth of all indicators in most areas was observed, and therefore the value of the integral index of production potential improved year after year. But this tendency is not typical for all regions of Ukraine. The presence of significant regional differences in development requires the introduction of an effective arrangement for implementing the regional policy of Ukraine.

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Non-Iterative Neural-Like Predictor for Solar Energy in Libya

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Abstract. In this paper, a new method for predicting the solar radiation potential in Libya was developed. It is constructed on the basis of the combined use of RBF and non-iterative paradigm of the artificial neural networks construction - the Successive Geometric Transformations Model. This method has the advantages of both approaches - the high prediction accuracy from RBF characteristics and fast non-iterative learning provided by the Successive Geometric Transformations Model. A series of practical experiments were conducted. The training model contained 1440 vectors of the monthly solar radiation, which recorded in 25 Libya's cities from 2010 to 2015. The test model contained 360 data's vectors. Comparison of the proposed method with existing ones is presented. The proposed method showed the best prediction results (MAPE, RMSE) compared to SVM, Linear Regression, the linear Neural-like structure of the Successive Geometric Transformation Model (SGTM), and the RBF based on the NLS SGTM. The proposed approach can be used in different areas, such as e-commerce, material science, images processing and others, especially in Big Data cases.

Keywords: Renewable Energy, Neural-Like Structure, Solar-Radiation Potential, Successive Geometric Transformations Model.

1 Introduction

The reserves of renewable energy on Earth are enough to meet all human needs today and in the distant future. Renewable energy sources, the presence of which is due to traditional physical processes on the Earth's surface and at some depth of the earth's crust, accompanied people at all times in its history, and they were the first sources of energy that people began to use meaningfully. Here you can name sails, water and wind mills, wave energy converters, and so on.

The potential of renewable energy sources in the world is substantially higher than the amount of all currently consumed fuel and energy resources [1]. Its rational use will solve a number of problems associated with environmentally hazardous processes for the carbon fuel processing and its savings. In the modern world, energy is the basis for the national economic base industries development, which determines the social production progress [2]. Taking all this into consideration, the use of the power generation alternative sources, in particular, solar energy, is an additional incentive for industrial development, employment and people's living standards, and, ultimately, strengthening and stimulating the economy [3]. All this prompts the intensification of the solar energy use since it can effectively transform into heat and electricity and be used for different consumer needs. The construction of such systems requires, among other things, accurate predicted data on the solar radiation level in a given region [3]. Such information will provide the opportunity to optimize the spent resources for the construction of alternative terrestrial energy [4]. The geographic location of Libya (Fig. 1) (relative humidity, temperature, sunshine duration), as well as meteorological parameters (month, longitude and latitude) (Table 1), suggest that there is sufficient amount of solar radiation in this area [5].

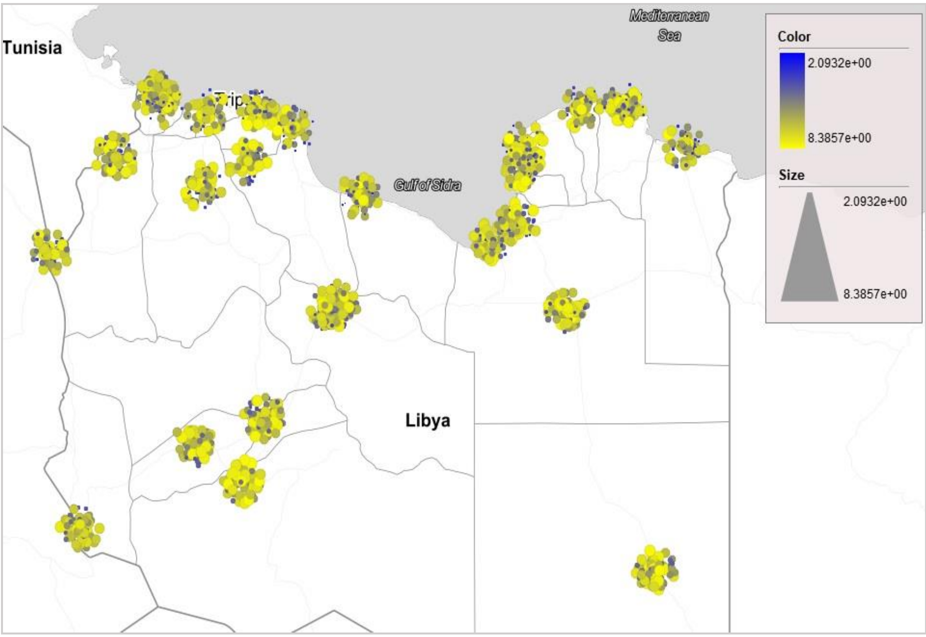


Fig. 1. The map of Libya cities used for prediction (based on Orange Software version 3.8.0).

Collected statistical data [5] in 25 cities of Libya in the period from 2010 to 2015 shows the level of solar radiation, ranging from 2.09 to 8.39 kWh / m2 / day, with average temperature variations in the region of 7 to 35 Celsius.

Table 1. Solar radiation statistical indicators for the period 2010-2015 at 25 cities in Libya.

Indicators							
Month	Latitude	Longitude	Elevation	Mean Temperature	Relative Humidity	Mean sunshine duration	Daily solar radiation

The aim of this work is to describe the developed solar radiation prediction method, which would provide the best results (based on Mean Absolute Percent Error - MAPE, Root Mean Square Error – RMSE, Mean Absolute Error - MAE [3, 6, 7].

2 Predictors Based on the Known Methods

The use of modern computational intelligence tools provides good results, but training models of such systems require a large sample of data [8, 9]. In addition, iterative algorithms for their training are quite slow [10, 11]. The developed linear methods of the solar energy predicting on the basis of SVM [12-16] are characterized by a number of shortcomings. In particular, such methods are sensitive to noise and data standardization. In addition, they are slowly training. Prediction methods based on linear regression [17-19] show satisfactory results only for short-term prediction with stable data. But with a sharp change, they give too many errors. Using such methods may result in an incorrect prediction, which may cause significant damage.

In this paper, we conducted an experimental evaluation of the above methods performance (according to RMSE, MAPE, MAE). The training sample from [5] was used for the experiment. It contains a collection of 1800 data’s vectors about the state of solar radiation in 25 cities of Libya for 6 years. The attributes of each vector are given in Table 1. The sample was randomly divided into halves - on the training (80%) and the test (20%) data. It should be noted that the same data was used to solve the problem by the proposed method.

The results of the solar radiation potential prediction in Libya using the SVM-based method and Linear Regression are shown in Fig. 2. We use the Orange software (version 3.8.0) for obtaining these results.

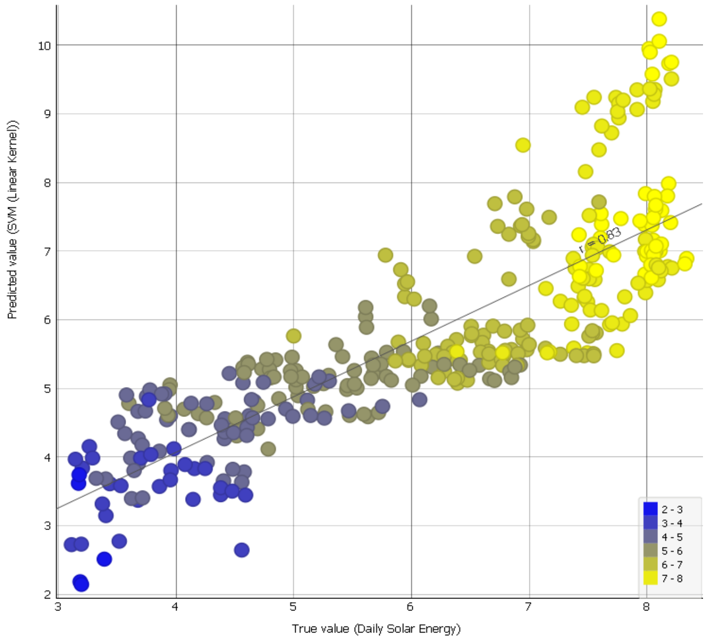
Table 2 presents the results and parameters of both methods comparison using.

Table 2. The comparison of the predicted results by the known methods (obtained by using Orange software).

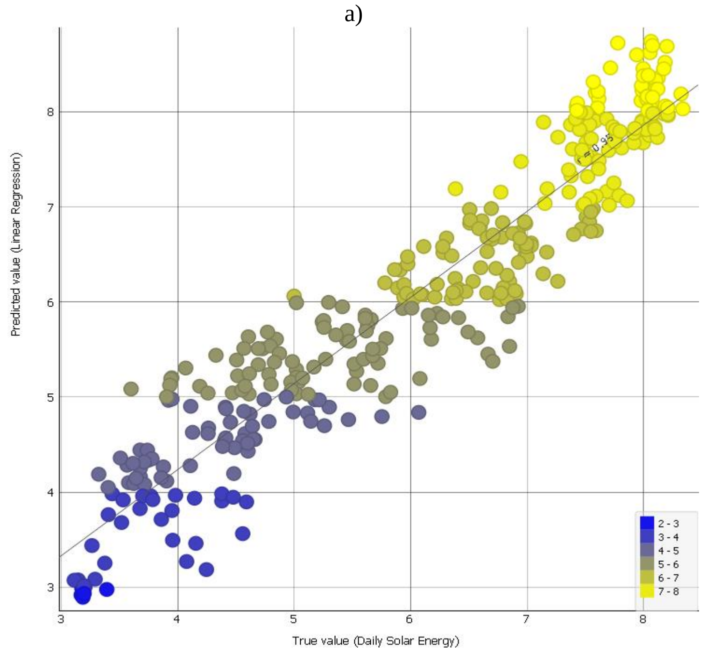
Method	Parameters	RMSE	MAE	MAPE, %
SVM	Linear kernel; Cost: 1.0; Epsilon: 0,10; Numerical tolerance: 0,0010.	0.961497	0.963701	16.4687
Linear Regression	The horizon is equal to 1	0.503864	0.410635	7.3649463

As shown in Table 2, the prediction method based on SVM shows significantly worse results. This is also evident from Fig. 2.

Despite the best results of the linear regression method, its practical application at RMSE = 0.5 and MAPE=7.4 is also ineffective.



a)



b)

Fig. 2. Visualizations of the predicted results by known methods: a) SVM; b) Linear regression.

3 Short-Term Predictors Based on the Neural-Like Structure of Successive Geometric Transformations Model

Modern neural paradigms that are used to solve various different tasks are based on the use of the iterative learning procedures [20]. This causes both a number of advantages and disadvantages. The disadvantages include the impossibility of solution reproducing in connection with the random initialization of the initial parameters of one or another ANN. This imposes a number of limitations (especially in case of need to ensure repetition of the solution) on the use of such tools for solving a number of practical tasks. We propose a new non-iterative paradigm (without the random initialization of the initial parameters) for constructing ANN - the Successive Geometric Transformations Model (SGTM) [20, 21], in particular for solving the prediction task.

The architecture of the linear-type Neural-like Structure of a Successive Geometric Transformations Model (NLS SGTM) used to solve the solar radiation prediction task in Libya is shown in Fig. 3. In this scheme, x_i is the i^{th} input characteristic in the input vector, where $i = 1,...,n$ and y is the output. The ordered lateral connections between the hidden layer neurons reflect the dependence of each subsequent step of successive geometric transformations from the previous one.

The general training procedure for NLS SGTM is performed by means of step-by-step geometric transformations in $(n + 1)$ -dimensional implementation space, where n is the number of input attributes [20]. The main steps of the training procedure are [20]:

- to determine the longest axis of the ellipsoid of the inputs scattering, the direction along which will coincide with the first coordinate of the intermediate coordinate system, which is formed during the training process;
- to determine the ellipsoid axis dimension (the second input coordinate), and to approximate the remainder of the previous approximation step, etc.

In this algorithm, the principle of greedy learning is used, that is, the consistent calculation of the principal components that meet the requirements that are put forward to them. Based on this, the speed of the method is increasing and practical limitations on the task dimensionality are removes, for example, in comparison to the PCA method.

In general, the training results are the parameters of the intermediate coordinate system, and for the supervised mode training, the parameters of the elementary approximation surfaces for each step of the transformation.

The neural-like structure's training time is determined by known in advance the number of transformation steps and depends only on the hardware. A detailed description of the application of this computing intelligence tool in supervised and unsupervised modes is given in [20].

In [22-25], satisfactory results of both short-term and long-term of solar energy prediction using RBF network are presented. The main drawbacks of these methods are the "curse of dimensionality" that is typical for RBF networks as well as a large number of iterations that provide a poor performance. In [26], a new approach - RBF based on NLS SGTM for another task is presented. Its architecture is shown in Fig. 4.

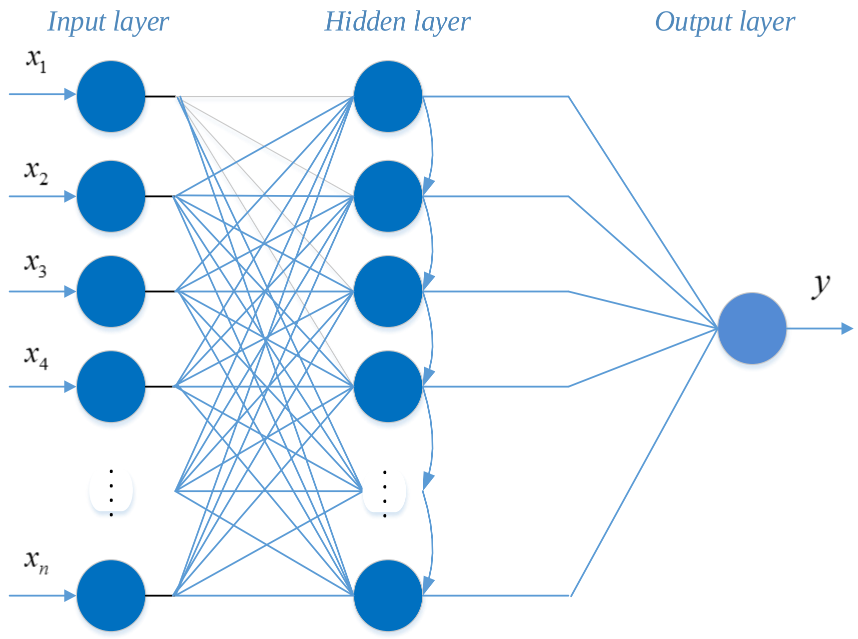


Fig. 3. The topology of the Neural-like structure of SGTM.

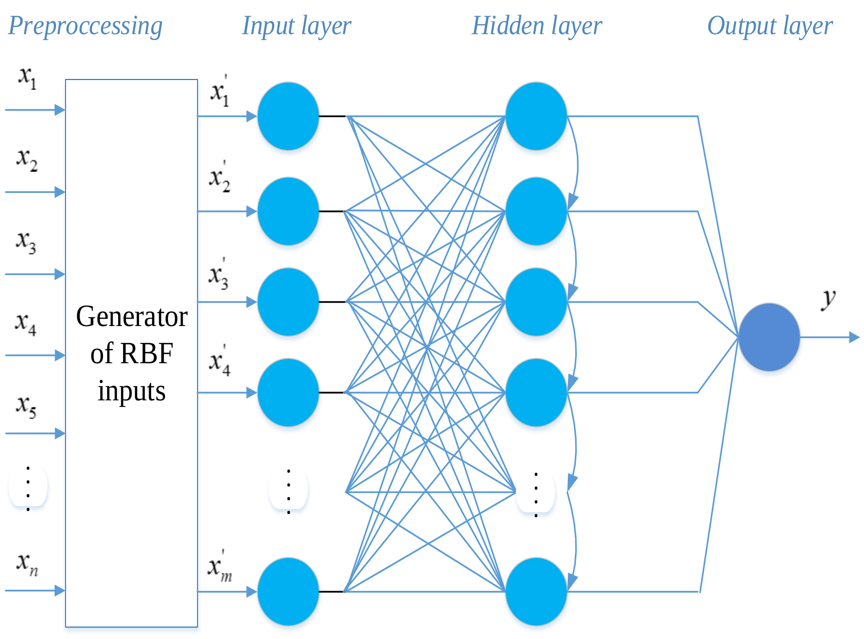


Fig. 4. The topology of the RBF based on the NLS SGTM.

RBF based on the NLS SGTM involves inputs signals transformation in the RBF inputs by the equation:

$$x_j^{'} = \exp\left(-\frac{D_j^2}{2\sigma^2}\right) \tag{1}$$

where [27]: σ is the tilt function parameter; D_j is a Euclidean distance between current vector point x_i, where $i = 1,...,n$ and j^{th} base, where $j = 1,...,m$ and m is dimensional of the RBF centers (user elects); $x_j^{'}$ is the magnitude of the signal appropriate to the RBF input.

The neural-like structure outputs are formed according to the classical representation of RBF-method in the form of a linear combination of the formed radial inputs.

Further training and use procedures of this ANN type correspond to the training and use procedures of the NLS SGTM [20, 27].

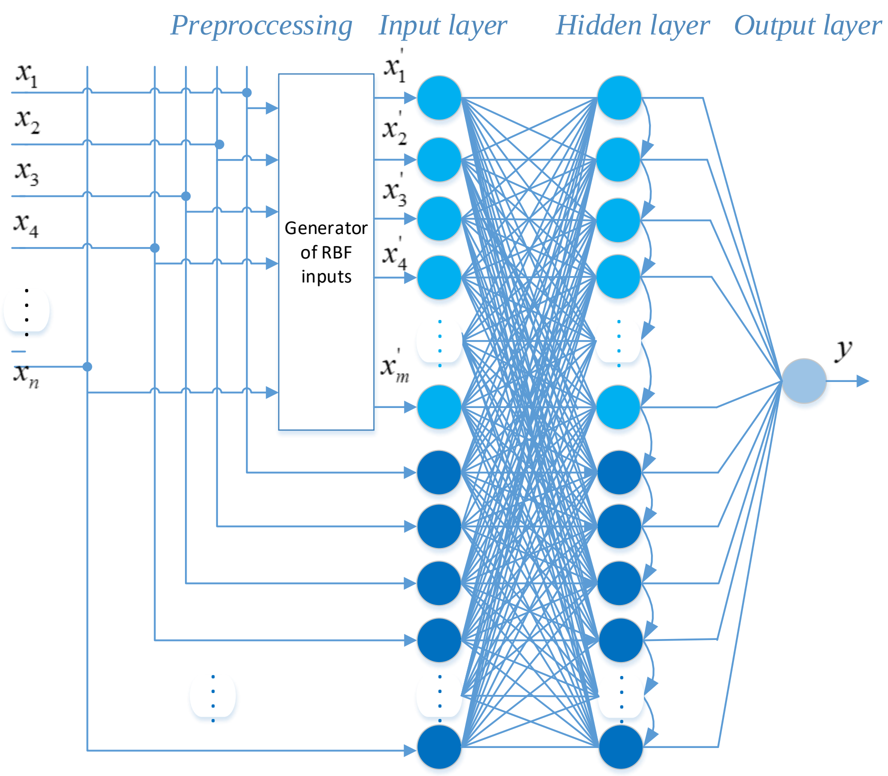


Fig. 5. The topology of the Combined RBF+SGTM neural-like structure.

In this paper, we propose the Combined RBF + SGTM architecture in the supervised mode for solving the prediction task. It is shown in Fig. 5**.**

Characteristics of such neural network combine the advantages of both used approaches - high accuracy, as well as non-iterative learning, which in turn greatly increases its speed. The peculiarity of the proposed Combined RBF+SGTM neural-like structure is that it solves the essential problem of the almost degenerate tasks, which often occurs when the method of radial functions is implemented.

4 Results and Discussions

The solar radiation prediction results (MAPE and RMSE) using NLS SGTM, RBF based on the NLS SGTM and the Combined RBF + SGTM are shown in Table 3. The best prediction results were obtained using the proposed method - Combined RBF + SGTM. Visualization of the method results is shown in Fig. 6.

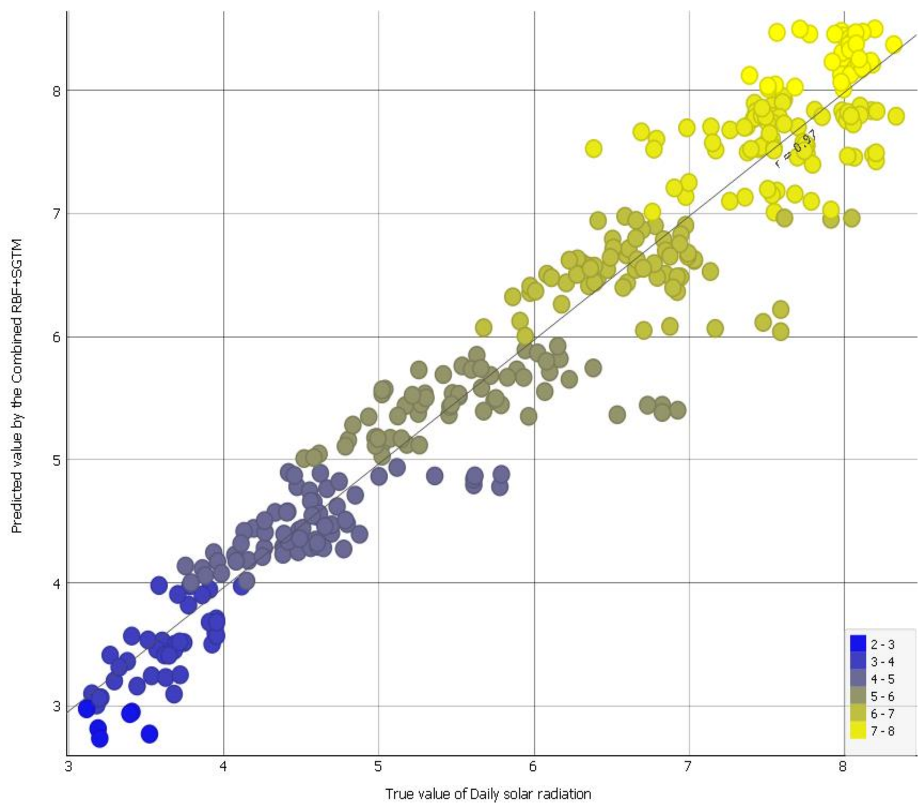


Fig. 6. Visualization of the prediction results by the proposed method.

The accuracy of all described methods in the paper is given in Fig. 7. As it can be seen, the lowest error (MAPE = 5.22) for solving the task of the solar radiation predicting in Libya provides the proposed method.

Further studies of the proposed approaches will be conducted in the direction of

Table 3. The comparison of the predicted results by non-iterative methods and proposed ones.

Method	Parameters	MAPE, %	RMSE	MAE
Linear NLS SGTM	7 inputs, 7 neurons in the hidden layer, 1 output	8.1694	0.5576	0.4310
RBF based on the NLS SGTM	100 inputs, 100 neurons in the hidden layer, 1 output	6.3519	0.6374	0.4064
Combined RBF+SGTM	107 inputs, 107 neurons in the hidden layer, 1 output	**5.2231**	**0.4105**	**0.3114**

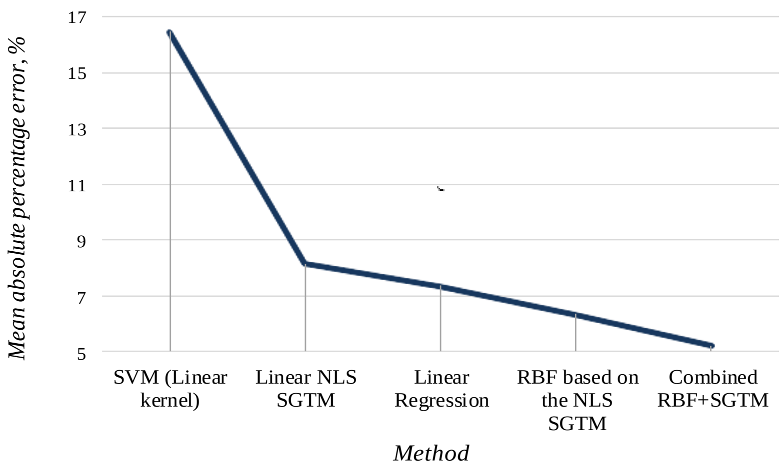


Fig. 7. Prediction accuracy comparison based on MAPE by all methods.

investigating the topologies and parameters of neural-like structures for solving prediction task, in particular, for determining the durability of the wheel pairs of rail transport [28] and high-pressure gas pipelines [29]. This will allow not only to save material resources but also to prevent possible man-made disasters.

5 Conclusion

In the article, the solution of the solar radiation prediction problem in Libya is described. The learning prediction model was based on seven geographical and meteorological indicators derived from 25 different Libya's cities over a period of 6 years. The training and test samples contained 14400 and 360 vectors respectively.

The disadvantages of SVM and Linear Regression prediction methods are described. An experimental analysis of their work was made.

In order to solve the prediction task, a method of computational intelligence on the basis of the combined use of RBF and the new paradigm of constructing artificial neural networks - the Successive Geometric Transformations Model was developed. The training process of such method (Combined RBF + SGTM) occurs in a supervised mode. Its main advantages are as follows: non-iterative training procedure; the similarity of training and using procedures; the high speed of work; high prediction accuracy.

An experimental comparison (based on MAPE and RMSE) of all methods described in the work is carried out. The smallest MAPE and RMSE was obtained by applying the proposed method.

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Recognition of Price Discrimination in the Online Sale of Airline Tickets

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Abstract. This paper deals with the recognition of price discrimination types in the online sale of tickets by Ukrainian airline companies. A set of technical tools, such as VPN, are used to create different user profiles in order to test several hypotheses on user features, which can make companies set different prices for similar tickets. A set of hypotheses is taken from already existing researches on price discrimination. Moreover, a new hypothesis about price discrimination based on geographical location of a customer will be tested.

Keywords: Price discrimination, dynamic pricing, VPN, airline industry.

1 Introduction

The use of dynamic pricing by companies is not a secret for customers for already many years. Industries that have high fixed costs widely use the approach of dynamic pricing in order to stay profitable. Usually, customers do not perceive this approach negatively, unless it refers to the use of personal information to establish different prices to people based on user profiling. A classic example of an industry that has high fixed costs and uses dynamic pricing on regular basis is the passenger airline industry. Since the costs spend on one flight do not depend much on the number of passengers but on fuel price and airport service costs, airline companies try to sell tickets for the highest possible price corresponding to the current demand. Based on many factors, such as time left to the departure, seasonal demand, the popularity of direction and other, airline companies set prices dynamically, usually the same for all users. Thus, companies provide sales for the highest price, so that the supply of seats in a plane is fully covered. However, many studies have shown that apart from using dynamic pricing synchronically users can become “victims” of the use of personal profiling information. It can be the case of price reduction for a person, who does not want to buy a ticket for its regular price. However, usually, it means that the price can be higher due to a detected ability to pay more.

Current research is dedicated to experimental testing and recognition of personal price discrimination in the online sale of Ukrainian airline companies’ tickets. The main goal of this study is to test several hypotheses on approaches that Ukrainian companies use for dynamic pricing. We want to make an emphasis on the aspects, which let us make conclusions on the use of personal profiling features while pricing. In case of the presence, we will be able to claim that Ukrainian airline companies do discriminate their customers based on personal features. In order to do so a set of tasks has to be completed:

1. Examine recent studies of dynamic pricing in the airline industry and allocate those examples, which refer to discrimination based on personal characteristics of a customer.
2. Make an overview of dynamic pricing software presented on the market.
3. Select Ukrainian airline companies, which make regular flights, to take part in the research.
4. Suggest some more hypotheses on features, which possibly can cause the use of personal pricing discrimination towards a specific profile.
5. Create fictive user profiles having specific features in order to test whether prices are sensitive to the profile differences.
6. Create experiments specification for testing hypotheses. Collect data on airline ticket prices under different profiles.
7. Analyze results and check different types of hypothesis about profiling features significant for dynamic pricing.

By solving these issues we will be able to detect approaches used by Ukrainian airline industry for dynamic pricing and compare methods with those, recognized in other studies of foreign companies. Thus, a conclusion about the presence or absence of personal price discrimination will be made.

The creation of several user profiles became significantly easier and affordable due to the drop in prices of VPN services. In turn, there is no need for a big amount of different devices or Internet access points in order to simulate "different people". Moreover, this study is the first academic one to deal with the personal dynamic pricing issue for Ukrainian airline companies.

The results of this study will be possible to use by both companies and their customers, however making an opposition between them. After becoming familiar with the results, companies will become aware of the methods their competitors use and those – presented in foreign business models. In their turn, customers will get more information for better decision-making. In case personal discrimination methods are used, they will gain tools to control pricing towards them based on ICT.

2 Personal Price Discrimination and ICT for Dynamic Pricing Strategies Support in Recent Studies

In this part, a review of studies, dedicated to testing of different hypotheses on personal price discrimination, will be made. Such issues as pricing based on days left to the flight or other factors, which is a reason to update prices for all users at a time, will be omitted here since they do not refer to pricing based on profiling. First, some examples of indirect profile discrimination will be given, further, we will move towards direct profile price discrimination.

One of the main price discrimination strategies that are used by companies is a so-called implicit segmentation [1] when the price of a round trip depends on the duration of stay (amount of time between the direct and return flights). This type of discrimination is rather indirect because anyone can check the price for a round trip with a different gap in time. However, from the point of human logic, a short flight seems to be a business trip or other urgent issue, which has to be solved on a specific time, while longer trips are supposed to be leisure ones. And this logic can be used in dynamic pricing algorithm to sell tickets with a higher price. According to [1], a price difference of 50% could have been observed for KLM company tickets prices in favor of long-term travelers compared to short-term.

Another example of indirect price discrimination is higher ticket prices for those, who scan websites on weekends rather than on working days. According to [17], people were offered in average 5% lower prices on weekends compared to working days. "This conjecture is supported by the finding that the weekend purchase effect is distinctly larger on routes with a mixture of both business and leisure customers than on routes that disproportionately serve leisure customers" [17].

One of the most popular and used for a long time approaches in dynamic pricing is a Saturday-night stay-over requirement for price discrimination. Concerning, that business trips usually take place on working days and busy people want to get home before the following weekend, there is a usual assumption that busy people do not leave for weekends, while those who have holiday trips can stay on weekends. Since the second group has a lower elasticity of demand, it is frequently offered tickets for lower prices. The research [20] showed a negative significant correlation between price of tickets and cases of covering weekend days during a trip. The very same result of a significant drop in price for Saturday-night stay-over trips was shown in the research [10].

Now let us move to the cases and assumptions of direct personal price discrimination in the sale of airline tickets. The research [6] concludes that customer browsing history and behavior on Internet causes price differences from one profile to another. An earlier study emphasized that customers are aware of the fact that their Internet profile can be used for dynamic pricing and individual price targeting [2]. Moreover, another study [11] showed that customers feel treated more fairly when they are offered different prices based on purchase characteristics rather than on their behavior and browser cookies history.

One of the features that can be taken from the browser cookies is whether a user has previously visited a mediator website in order to find suitable fares. If so, then a further direct visit to a company website can be impacted by the previous action. The fact of possible price change in the airline industry was not checked itself, however, the research about pricing on the Internet [8] showed, that such a strategy is widely used in e-commerce and online sales. The hypothesis to check in this research is a decrease in a price of tickets after visiting a mediator website.

Here is the list of top discrimination types detected by researchers at different studies referring to airline tickets sale and pricing on the Internet. All these direct and indirect types of discrimination by the user profiling will be tested in the main part of this paper on Ukrainian airline companies.

Now let us consider those technologies standing behind dynamic pricing strategies. The need for dynamic pricing is not a whim of companies. It has become the norm for many service industries – especially in today's volatile markets. Due to the intensification of competition in the markets, companies should care about a proper pricing strategy. Information now is more available than ever before, that is why an average customer became significantly aware of prices on market, competitive advantages of companies. "How you price your product could make or break your business. Price too high and you'll likely lose to the competition. Price too low and you'll degrade the value of your goods and services. Price just right, and you've put yourself in prime position to win the sale. Bottom line: you need a strong, sound, and proactive strategy to come out on top" [13].

The main reason for the rapid development of pricing strategies its and continuing improvement is the new sources of information. "Technological advancements are giving airlines access to more information about the characteristics of their customers" [4]. Implementation of a dynamic pricing strategy and revenue optimization in today's information world is gained by the use of up-to-date ICTs, recent methods of artificial intelligence, such as neural networks and reinforcement learning, and nature-oriented optimization methods, such as genetic algorithms and simulated annealing. These methods are being developed constantly and specialists apply them to allocation processes in distributed IT-infrastructures, or grid systems [7, 16, 19].

Currently, several dozens of specialized software, both web-based and desktop, can be found. These products provide a different kind of analytics in addition to pricing strategies. They are channel analysis, competitor product analysis, market analysis, pricing analytics etc. According to Capterra ranking of the highest rated products,[1] the top three dynamic pricing software products are Prisync, Seller Republic, and Skuuudle. Another ranking set by G2 Crowd gives first three places to aPriori, EndeavorCPQ, Verenia CPQ. If we consider a company's size, the best products for big enterprises are KBMax3D CPQ, aPriori Product Cost Management, and Zilliant IQ. For mid-market companies, G2 Crowd recommends EndeavorCPQ, Verenia CPQ and KBMax3D CPQ. EndeavorCPQ is proposed for small business as well.[2]

According to the interview with 7 dynamic pricing software specialists on Quora, it is obvious that the use of simple business rules without analysis of specific data is a poor game. All of them agree with the opinion that big data needed for machine learning and deriving pricing rules is the core of an effective strategy. They also make an emphasis on the need for quality data that should be used for learning, since the effectiveness of pricing highly correlates with it. However, a reasonable approach for choosing software products was proposed by a pricing consultant Kapil Muley. He insists on building custom models for any kind of company in order to correspond to the specifics of the company industry.[3]

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1 https://www.capterra.com/pricing-optimization-software/?utf8=%E2%9C%93&users=&sort_options=Highest+Rated

2 https://www.g2crowd.com/categories/pricing

3 https://www.quora.com/What-is-the-best-software-for-fully-automated-dynamic-pricing-in-e-commerce

3 Ukrainian Passenger Airline Industry

In this part, we are going to make a review of Ukrainian companies, which carry out regular passenger flights. Today only 4 airline companies deal with regular flights and have their own Internet platforms for selling tickets online. After "Aerosvit" company went bankrupt in 2012, "Ukrainian International Airlines" became an actual monopoly-company and still being so far. Here is the list of companies whose pricing approaches will be analyzed in this work:

1. Ukrainian International Airlines – a strategic Ukrainian company, which carries out most of the international flights from Ukraine. The company is based at Boryspil International Airport. "Ukraine International offers a vast selection of point-to-point and transit travel opportunities. The airline connects Ukraine with 38 countries in Europe, Asia, America, Africa, and the Middle East. The carrier operates 1100 international and domestic flights weekly and provides connections with partner airlines' services to over 3000 destinations worldwide"[4].

2. "Motor Sich Airlines" – a unit of the Public Joint Stock Company Motor Sich, a successful and leading company, which develops and manufactures aircraft and helicopter engines. The company is based in Zaporizhzhya International Airport. "Nowadays the Airline has a fleet of nine aircrafts, operating regular passenger domestic and international flights, passenger and cargo charter flights and special flights, ensuring operation of the parent company".[5]

3. "Atlasjet" – a subsidiary company of Turkish "Atlasglobal", was licensed only a few years ago, in 2015. "Atlasglobal performs regular international flights from Lvov, Kharkov, and Zaporozhye to Ataturk airport in Istanbul, from Istanbul – to the cities of Turkey, Northern Cyprus, Europe, Russia, Caucasus, Central Asia and the Middle East".[6] Ukrainian subsidiary is based in Lviv Danylo Halytskyi International Airport.

4. "Yanair" – another young airline company, based in Kyiv International Airport (Zhuliany). The company carries out both regular and charter flights, the regular ones have destinations in Georgia and Israel. Apart from passenger air travel, the company implements an investment program into Zhytomyr Airport.[7]

It is worth noting that the companies mentioned above have a very different market position, since "Ukraine International Airlines" seems to be a monopoly-company and has the biggest market share. Formally, the company is not recognized as a monopolist in Ukraine, since "market" in the airline industry is defined as the set of flights on the respective route. Thus, formally a monopolist should occupy all the routes from the country. According to the Ministry of Infrastructure of Ukraine, the number of transported passengers by "Ukraine International Airlines" during the first three quarters in 2017 was 20% higher than during the similar period in 2016.[8] "Ukraine International Airlines" has overall transported nearly 7 million of passengers during the

4 https://www.flyuia.com/ua/en/about/uia-about
5 https://www.flymotorsich.com/en/pages/company
6 http://www.atlasglb.com.ua/about-us/
7 http://yanair.ua/company.html
8 https://mtu.gov.ua/content/statistichni-dani-v-galuzi-aviatransportu.html

previous year,[9] which is about 68% of 10.55 million people transported by Ukrainian airline companies in 2017.[10] Considering this, we percept "Ukraine International Airlines" as a monopolist of the industry.

4 User Profile Simulation and Significant Features Detection Methodology

This part contains specifications of several experiments conducted in the framework of this study. In general, we expect to recognize some cases of the third-degree price discrimination, which implies customer segmentation in order to sell tickets for different prices. The worst possible case we should expect to recognize is the first-degree price discrimination, which means selling tickets for the highest acceptable by a certain customer price. However, only a monopolist can afford using such technique for pricing. First of all, let us define the hypotheses we want to test. Besides what was mentioned in the previous studies part, there are several more hypotheses to add, which mostly refer to personal profiling features of a user. Here is the final list of ten hypotheses to check (Table 1), including an explanation of why these features are important to test. Assumptions on the possible impact of these features on tickets' price can be found as well.

Table 1. Hypotheses on user features, which can be used for discrimination while dynamic pricing

#	Discriminated feature	Direct or indirect discrimination type	Why this feature is important	Hypotheses to test
1	Saturday-night stay-over	Indirect	Business trips, which are more price elastic, are not supposed to occur on weekends	Round trips that overlap weekend days are cheaper

9 https://www.flyuia.com/ua/ua/news/2018/uia-performace

10 http://cfts.org.ua/news/2018/01/16/ukrainskie_aviakompanii_uvelichili_passazhiropotok_na_275_v_2017_godu_45009

#	Discriminated feature	Direct or indirect discrimination type	Why this feature is important	Hypotheses to test
2	A user has previously booked a hotel	Direct	Since a person has some fixed plans, he or she is less price sensitive	Round trip is more expensive after a hotel has been booked
3	Geographic location	Direct	People from all over the world have different financial opportunities, proportional to the incomes of the country's population	Users from developed countries will be offered higher prices than those from developing ones
4	Cookies and general search history left in a browser	Direct	Since a company can reconstruct more precise profiles of people, they will be offered prices fitting their behavior	Depending on the browser history, people can be offered both lower or higher prices compared to „cold“ (newcomers without information collected) users
5	Other company same direction previous search	Direct	A company can vary prices depending on the knowledge of a user about prices offered by competitors	Depending on the prices offered by previous search result of the same direction, cross-price elasticity may vary
6	Previous unfinished attempt to buy tickets	Direct	A company can create an impression of urgency to make a quick decision before prices have changed again	Prices increase after an unfinished attempt to buy tickets
7	Duration of the stay	Indirect	Business travelers, who are less price sensitive, and leisure travelers differ in the length of a trip	The longer the round trip – the less is the price

#	Discriminated feature	Direct or indirect discrimination type	Why this feature is important	Hypotheses to test
8	Day of week to purchase tickets	Indirect	People who buy tickets on weekends are more price sensitive	Prices go lower on weekends
9	Direct website visit or previous mediator website visit	Direct	Companies create a feeling of urgency to buy a ticket on a direct website since price here is lower	Companies can offer a lower price than the very same company's route on the mediator website
10	Device type	Direct	The type of device a person uses correlates with financial opportunities	Customers browsing the internet from expensive devices will be offered higher prices

An approach used in this study for testing hypotheses includes creating several fictive user profiles and conducting A/B testing. An important condition for correct calculations is to isolate the impact of other user factors for each tested feature. Hypotheses about indirect price discrimination types do not need A/B testing since they are not supposed to depend on user profiling features.

For this study, several fictive customer proflies were created. This is possible due to the use of virtual private network (VPN) service, namely IVPN,[11] that gives an opportunity to go to a website using a mediator server. Thus 6 different browsers on different devices were used, plus servers around the world mediated them. Here is the list of profiles used for the experiment:

Table 2. Devices used for the experiment

#	Browser	Cookies history	Servers	Platform
1	Mozilla	Cleared	Paris, Toronto, Hong Kong	Windows
2	Google Chrome	Cleared	Madrid	OS X
3	Safari	Not cleared	-	iOS
4	Safari	Not cleared	Bucharest	OS X
5	Google Chrome	Not cleared	Milan	Windows
6	Google Chrome	Cleared	Frankfurt	iOS

[11] https://www.ivpn.net/

Now we need to specify experiments for testing hypotheses from Table 1. It is important to make sure that metrics in the A\B test are isolated from the impact of other factors (or at least this impact is not significant).

Table 3. Experiments specification and explanation

Exp. #, name	Control metric	Platform, browser, server	Test metric	Platform, browser, server
1. Saturday-night stay-over	Round trip price (trip does not weekend) divided by the sum of one-way component flights	Windows Mozilla No cookies Paris	Round trip price (trip includes weekend) divided by the sum of one-way component flights	Windows Mozilla No cookies Paris
2. Previously booked a hotel	Round trip before booking a hotel	Windows Mozilla No cookies Paris	Round trip after booking a hotel	Windows Chrome Cookies Milan
3. Geographic location	One way trip	Windows Mozilla No cookies Paris	One way trip from other servers	Windows Mozilla No cookies Toronto & Hong Kong
4. Cookies and general search history left in a browser	One way trip	iOS Chrome No cookies Frankfurt	One way trip	iOS Safari Cookies Kiev
5. Other company same direction previous search	One way trip	iOS Chrome No cookies Frankfurt	Check same direction price on different airline company website, then check the one-way trip price	iOS Safari Cookies Kiev
6. Previous unfinished attempt to buy tickets	Roundtrip	OS X Safari Cookies Bucharest	Round trip, after previous attempt to book on the same device	OS X Safari Cookies Bucharest

Exp. #, name	Control metric	Platform, browser, server	Test metric	Platform, browser, server
7. Duration of the stay	3 pairs of separate round-trip flight components, try three different timeframes: up to 3 days, nearly a week, more than 10 days	Windows Mozilla No cookies Paris	Round trip, try three different timeframes: up to 3 days, nearly a week, more than 10 days. Check the sum divided by the sum of one-way component flights	Windows Mozilla No cookies Paris
8. Day of week to purchase tickets	Round trip price on a working day	Windows Mozilla No cookies Paris	The same round trip price on the weekend, then again on working day	Windows Mozilla No cookies Paris
9. Direct website visit or previous mediator website visit	One way trip	iOS Chrome No cookies Frankfurt	Check same direction price on mediator website, then check the price on the direct website	iOS Safari Cookies Kiev
10. Device type (platform)	Roundtrip	Windows Mozilla No cookies Paris	Compare with the same search on other devices	iOS / OS X No cookies

Let us bring some understanding of testing hypotheses about indirect price discrimination. As it was shown in the specification of #1 experiment about Saturday-night stay-over, we aim to check, how price of the round trip differs from the total price of two separate tickets as if they were bought separately. For example, as for January 17th, the price of the race Kyiv-Vienna conducting on February 6th by Ukraine International Airlines was 6439 UAH. The return flight from Vienna to Kyiv on February 9th cost 7073 UAH. However, if we buy the respective round trip in one cheque, the two tickets would cost 7256 UAH, meaning, that the discount for buying them is around 46%.

While collecting routes data for the statistics, we tried to select quite similar trips. In the case of experiment # 1, the round trips compared should have the same time of stay and nearly the same price. This can prevent from the impact of undesirable factors on the experiments.

5 Results and Discussions

During this research, we have collected 920 flight price observations (later grouped into 400 test cases), established by Ukrainian airline companies. These were both one-way ticket prices and round-trip prices. For the purpose of creating 6 different fictive profiles, we have used only 2 devices: iPhone 6s and MacBook Pro Retina 2015.

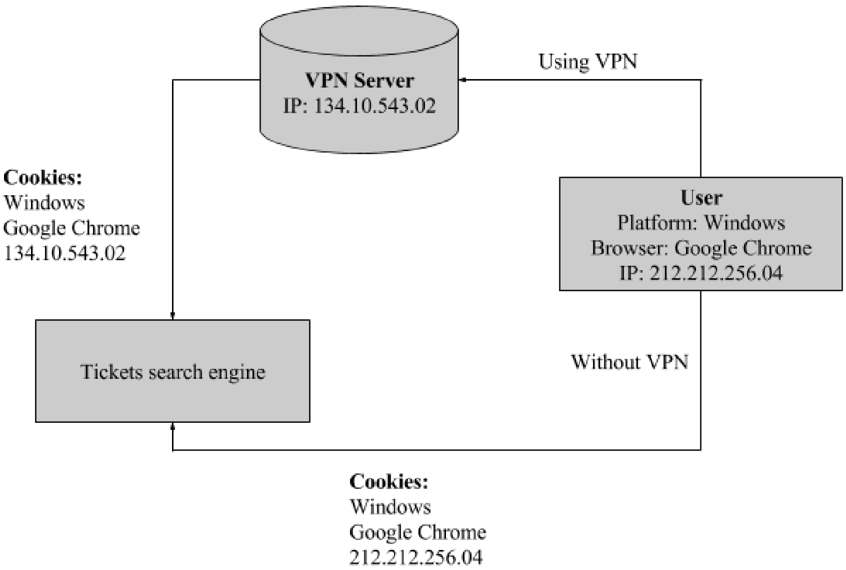

Fig. 1. A scheme of changing IP address in cookies while using VPN.

A virtual Windows machine was created on Macbook using VirtualBox and official 3-month trail Windows distributive for virtual machines. Thanks to the use of IVPN service we could use 6 different servers from cities of different continents (Paris, Madrid, Frankfurt, Milan, Hong Kong, Toronto) to use IP addresses, which helped with imitating 6 different people. In Figure 1 a scheme with an example of VPN service use is explained.

After collecting data, which might theoretically belong to different people, we analyzed the results in order to recognize those cases, which prove the use of price discrimination based on indirect factors and direct user profile features. The results are presented in Table 4. By “proving” cases we mean those ones that can be associated with a certain hypothesis acceptance, while “neutral” cases – with rejection.

Table 4. Experiments' specification and explanation

Company	Hypothesis tested	# of proving cases	# of neutral cases
Ukraine International Airlines	1. Saturday-night stay-over	5	5
	2. Previously booked a hotel	1	9
	3. Geographic location	0	10
	4. Cookies and general search history left in a browser	0	10
	5. Other company same direction previous search	0	10
	6. Previous unfinished attempt to buy tickets	0	10
	7. Duration of the stay	3	7
	8. Day of week to purchase tickets	0	10
	9. Direct website visit or previous mediator website visit	0	10
	10. Device type (platform)	0	10
Motor Sich Airlines	1. Saturday-night stay-over	2	8
	2. Previously booked a hotel	0	10
	3. Geographic location	0	10
	4. Cookies and general search history left in a browser	0	10
	5. Other company same direction previous search	0	10
	6. Previous unfinished attempt to buy tickets	0	10
	7. Duration of the stay	4	6
	8. Day of week to purchase tickets	1	9
	9. Direct website visit or previous mediator website visit	0	10
	10. Device type (platform)	0	10
Atlasjet	1. Saturday-night stay-over	6	4
	2. Previously booked a hotel	0	10
	3. Geographic location	0	10
	4. Cookies and general search history left in a browser	0	10
	5. Other company same direction previous search	0	10
	6. Previous unfinished attempt to buy tickets	0	10
	7. Duration of the stay	5	5
	8. Day of week to purchase tickets	0	10

Company	Hypothesis tested	# of proving cases	# of neutral cases
Atlasjet	9. Direct website visit or previous mediator website visit	0	10
	10. Device type (platform)	0	10
Yanair	1. Saturday-night stay-over	0	10
	2. Previously booked a hotel	0	10
	3. Geographic location	0	10
	4. Cookies and general search history left in a browser	0	10
	5. Other company same direction previous search	0	10
	6. Previous unfinished attempt to buy tickets	0	10
	7. Duration of the stay	3	7
	8. Day of week to purchase tickets	0	10
	9. Direct website visit or previous mediator website visit	0	10
	10. Device type (platform)	0	10

Concluding from the results, reflected in Table 4, we cannot prove any kind of direct personal discrimination by Ukrainian companies while selling tickets online. This means, that our possible believes about airline companies (at least in Ukraine), who might use our personal information to manipulate prices, are groundless. Another situation we have with indirect personal price discrimination. We saw some cases when a price for the round trip can vary depending on Saturday-night stay-over and the length of a trip planned. However, these experiments can have other impacting factors, which were not taken into consideration. For example, it seems that prices are less likely to have big discounts for round trips as soon as time till departure decreases.

It is worth noting, that the results on direct discrimination type are quite significant to consider them as the disapproval of personal price discrimination used by Ukrainian airline companies.

6 Conclusions

The conducted research leads to several conclusions. The first and the most important conclusion refers to the issue of personal price discrimination while selling tickets by airline companies. No significant proves of using personal information from cookies by Ukrainian airline companies have been found. Moreover, one of the provoking hypotheses that geographic location of a customer has an impact on tickets price was refuted. This entails the next set of conclusions for online tickets sale by Ukrainian airline companies:

- Previous browsing history of a user has no evidence of influencing ticket prices.
- The fact, that a user has already booked a hotel, does not affect the trip price.
- Geographic location of a user does not influence ticket prices.
- A fact that a user has checked competitors' prices on the same route has no impact on ticket prices, the same with mediator websites.
- Previous unfinished attempt to book tickets does not entail price increase.
- The type of device a customer uses to check ticket prices does not affect prices themselves.

Another piece of conclusions made during the research is that there is no direct evidence of using price discrimination based on so-called “indirect” user profile features, such as duration of stay, week of purchase and Saturday-night stay-over effect. However, these hypotheses need further research in case of interest towards these issues.

In this study, the authors have shown, how available tools can be used for checking price discrimination hypotheses for any kind of online sale platform. The main idea of this method is that VPN services can be used to create fictive user profiles. What is most important is that they would differ by IP address and geographic location respectively.

Several recommendations for customers to avoid price discrimination can be made based on the research and previous studies in the field. Browsing history and Internet footprint can be used for establishing prices dynamically based on browser cookies. It is reasonable to check the same item price from a browser with cookies used, and from a clear browser as well. It will not be superfluous to analyze your previous actions in a browser and how they can affect prices. Also, VPN services can be used for browsing websites as a specific country's resident. The authors of this work call customers for smart use of browser cookies and private browsing.

On the other hand, price discrimination is an approach for companies to expand markets and make extra profits. Using up-to-date information technologies is an opportunity for new selling approaches and dynamic pricing in general. Companies are getting new opportunities for wider price diversification and more effective extraction of customer surplus. This became possible due to the use of ICT for studying consumer preferences and behavior.

The absence of price discrimination detected while studying Ukrainian airline companies is not an unequivocal indicator of ethics. It rather shows that the companies are lacking ICT tools for dynamic pricing, which are unlikely used often in online pricing worldwide.

Thus, an important factor for increasing Ukrainian companies' competitiveness is their ability for discovering and using knowledge from all possible sources of information. Using dynamic pricing strategy is not a new concept, however still being possible with enough data and technologies. That is why Ukrainian airline companies should use a broader range of ICT in order to keep being competitive and increase efficiency.

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Universal Properties of the General Agent-Based Market Model through Computational Experiments

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Abstract. *Research goals*: to synthesize the general view market mathematical model in accordance with new dynamic paradigm of economics, to reveal the universal properties of general view markets.

During our investigation we developed and continuously improved a desktop C# application *Model* for support the research process using computing experiments. Here our task is revelation of the universal properties of general view market as a result of simulation experiments using this software module.
Results of the research: the crucial factors which ensure the market stability are the level of agreement in adaptive expectations and the share of planning with adaptive expectations in a market. The increase of naive expectations leads to stability loss, to bifurcations and finally to chaos in general view market. The increase of number of firms also leads to stability loss and finally to chaos in the general view market at appreciable naive expectations. We revealed that the profits ratio and quantity outputs ratio of firms remains almost unchanged in short-run period in general view markets. It seems an important stability factor of many important real markets for which chaotic dynamics is usual.

Keywords: agent-based model, heterogeneous type, bifurcation, adaptive expectations.

1. Introduction

Information technology in the economy made it possible to model artificial societies and study economic models through the computer simulation. Economics has entered the stage of deep transformation of its bases. In recent years the researchers are renouncing the assumption of perfect rationality as unconditional basis of economic agents' behavior [1]. The neoclassical 'rational man' does not exist in reality: economic agents act according to established rules, without being fully informed and maximizing their own utility [2].

The real economic processes make a clear demonstration that neoclassical "rational man" is not their subject. In real economy "optimal imperfect decisions" are taken by simple and non-expensive calculations, well adapted to frequent repetitions, to evolution: it is more efficient for perfectly rational firm to perform multiple experiments with quantity to estimate the demand function rather than search for nonrecurrent, instantaneous achieving of equilibrium [3]. All it means that the real economy is dynamical system, and real processes of economy are iterative processes of this system.

Now institutional school of economics analyzes economic systems as a result of evolutionary process of participants' interaction [4]. New paradigm of economics is a mix of the nonlinear dynamical system theory and mathematical programming, including game theory and optimal control theory [5]. And the main tool of new economics is simulation modeling grounded on the basis of 3 computer paradigms (object-oriented, dynamic and multi-agent system) [6].

This new economics allows explaining the phenomena which were not keeping within traditional schemes. The evolutionary approach and analysis of the dynamics allow to explain why one type of firm ousts another from the market, why sometimes the economic system is stable, but in other cases is unstable [3, 7]. If the system has multiple equilibriums, the dynamics and evolution is the selection mechanism of best equilibrium according to certain criteria [8]. Traditional static models of competition (e.g., Cournot, Bertrand and Stackelberg) were converted in dynamic models which were investigated on existence, stability and local bifurcations of the equilibrium points [9, 10, 11].

Within the limits of new economics it is natural to study reciprocity relations [12]. Reciprocity or social responsibility implies that the firms not only pursue their selfish goal of increasing profits, but are also ready to sacrifice some of their profits for the benefit of consumers without direct compensation for it by the state [13]. Such targets can be stipulated by the firms' desire to get stable profits in the long run rather than maximal short-run profits [14, 15]. Such forward-thinking firms-reciprocators are considered in this paper. Their objective function is a weighted average of the profits and consumer surplus of their market segment.

Modern development of dynamic paradigm in economics is a wide stream of researches. However it is a stream of examples which are not developing in the general theory; their relations with real markets are often problematic [16]. The traditional method of constructing a scientific theory is first to synthesize and investigate the simplest possible mathematical model. And then we can study complex real systems which are grounded on this basis. This traditional approach is taken as a principle of our research.

This paper is a continuation of our previous works [17], [18]. There the elementary market model corresponding to the new paradigm of economics has been synthesized and investigated. That model describes a simplest market where firms have only one difference in their type when some firms (egoists) are focused exclusively on short-run profits, while others (reciprocators) take into account long-run factors. However it`s not any special, specific market; actually any global market contains such elementary local markets and consists of them. As suggests common sense then dynamics of the global market is stratified on dynamics of such local markets. Therefore it was naturally to state a hypothesis that the derived in [17], [18] properties of the elementary model are universal, i.e. these properties are the properties of general view market including real markets as a special case. Check of this hypothesis makes the project of this work.

The **paper goal** is to synthesize the general view market mathematical model according to the new dynamic paradigm of economics, to reveal the universal properties of general view markets including real markets, to check up the hypothesis about universality of properties of the model [17].

During our investigation we developed and continuously improved a desktop C# application *Model* for support the research process using computational experiments. Our next task is revelation of universal properties of general view market as a result of simulation experiments using this software module.

The paper is organized as follows: in part 2 we synthesize the general view market model; part 3 demonstrates desktop application *Model* for computing experiments; sections 4.1 – 4.3 describe our market model researches using this application, section 4.4 formulates their results; part 5 concludes.

2. Agent-Based General View Market Model

In general, almost any microeconomic market model is constructed as follows: 1) n firms operate in the market (to simplify the notation suppose $n = 2$); 2) these firms produce homogeneous products in quantities $x_1(t)$ and $x_2(t)$ in time period t; 3) they use adaptive approach, i.e. they try to predict the quantity of their competitor in the next time period; 4) let $x_j^e(t+1)$ is the expected quantity of rival j by a firm i in next period $t+1$ ($i, j = 1, 2$). Then under planning of their quantity $x_i(t+1)$ in the next period the firms solve the following optimization problem:

$$Max\Pi_1(x_1(t+1); x_2^e(t+1)),\ Max\Pi_2(x_1^e(t+1); x_2(t+1)), \qquad (1)$$

where Π_i, $i = 1, 2$ is a profit function of firm i. The assumption about unchangeable quantity of the competitor (i.e. firm i will use $x_j(t)$ instead of $x_j^e(t+1)$ when it solves the optimization problem) is an example of imperfect, bounded rationality in firm's strategies; it is called naive expectations. As a rule these two approaches (adaptive and naive) coexist in the market with a certain probability. Our model is based on these assumptions.

We consider a market of homogeneous product, where exogenous parameter $n(t)$ indicates how many firms operate at time t. Each firm produces output $x_i(t)$, where $i = 1, ..., n(t)$. Thus the industry output of the market is $Q(t) = \sum_{i=1}^{n} x(t)$ at time t. Product price P is given by isoelastic demand function $P = P(Q) = b(t)/Q$ ($b(t) > 0$). Such kind of demand function as a matter of fact is not a restriction. Really, in a small neighborhood of a market state during the moment t any demand function with elasticity $b(t)$ differs from the isoelastic one a little. Then in short-run period dynamics of a market with such demand function differs a little also. And at a structural stability they are qualitatively (i.e. orbitally) equivalent.

Formally the firm is defined by its objective function. Firm maximizes both its own profit $\pi_X = (P - v) \cdot x - fc$ (where v is the firm's cost per unit in the market, fc is fixed cost) and consumer surplus CS (difference between maximum price which consumer can pay and real price) $CS = \Theta \cdot \left(\int_{\varepsilon}^{Q} P(q)dq - P \cdot Q \right)$, where parameter Θ specifies the segment of the market, which the firm believes its own and optimizes; ε is the minimal technologically possible product quantity. Then

$CS = \Theta \left(b \cdot \ln(\frac{Q}{\varepsilon}) - \frac{b}{Q} \cdot Q \right) = b\Theta \cdot \left(\ln(\frac{Q}{\varepsilon}) - 1 \right) = b\Theta \cdot \ln \frac{Q}{\hat{\varepsilon}}$, where $\hat{\varepsilon} = \varepsilon \cdot e$ (specific choice of ε does not affect the model dynamics and so we suppose $\varepsilon = 1$). Then general profit function $\Pi = \Pi_i(t)$ of firm is:

$$\Pi = \alpha \cdot \pi + (1-\alpha) \cdot CS = \alpha \cdot ((P - v) \cdot x - fc) + (1-\alpha) \cdot b\Theta \cdot \ln \frac{Q}{\varepsilon}, \qquad (2)$$

where $\alpha = \alpha_i(t)$ is share of short-run own profit $\pi = \pi_i(t)$ in the objective function, $1-\alpha$ is share of consumer surplus CS, $fc = fc_i(t)$ is a fixed cost. As a matter of fact Π is a weighted average of short-run profit π and expected stable long-run profit.

The model of paper [17] is the elementary special case of this general model. There we consider a market of homogeneous product, where n firms operate, among them are k identical reciprocator firms with the same output x and $n-k$ identical selfish firms with the same output y.

Dynamic of the model is considered for discrete time $t = 1, 2, \ldots$. Our model is uniquely defined by firms' objective functions and their expectations types. It does not use any additional assumptions or restrictions.

2.1 Dynamics Model Equations

In real life both decision making approaches (adaptive and naive) coexist in the market with a certain probability. Let's obtain now the equations of a general market model with the minimum account of adaptive expectations dictated by common sense. According to such expectations firm i suggests that production quantities of its rival j will be equal to $x_j^e(t+1) = \delta_{ij}(t)x_i(t+1) + \chi_{ij}(t)x_j(t)$. Here $\delta_{ij}(t) \geq 0$ and $\chi_{ij}(t) \geq 0$ are parameters, defining shares of naive and adaptive expectations at this planning.

Let $z_i = x_i(t+1) + \sum_{j \neq i} x_j^e(t) = \sum_{j=1}^{n(t)} \delta_{ij}(t)x_i(t+1) + \sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t)$ is prospective industry output of the market, where $\delta_{ii}(t) = 1$, $\chi_{ii}(t) = 0$. Then the objective function for the firm i has the form $\Pi_i = \alpha_i((\frac{b}{z_i} - v)x_i(t+1) - v_0) + (1-\alpha)b\Theta_i \ln(z_i)$ in accordance with (2) (here $\varepsilon = 1, \alpha_i = \alpha_i(t)$). Then according (1) the point $x_i(t+1)$ of maximum objective function Π_i is found from the condition

$$\frac{\partial \Pi_i}{\partial x_i(t+1)} = \alpha_i\left(\frac{bz_i - \sum_{j=1}^{n(t)} \delta_{ij}(t)\cdot bx_i(t+1)}{z_i^2} - v\right) + (1-\alpha_i)b\Theta_i \frac{\sum_{j=1}^{n(t)} \delta_{ij}(t)}{z_i} = 0.$$ Then

$$z_i^2 = \frac{b}{v}\sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t) + \frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\sum_{j=1}^{n(t)} \delta_{ij}(t)z_i. \tag{3}$$

Hence suppose that $d_i = \frac{1}{2}\frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\sum_{j=1}^{n(t)} \delta_{ij}(t)$ we obtain

$$(z_i - d_i)^2 = \frac{b}{v}\sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t) + d_i^2; \qquad z_i = \sqrt{\frac{b}{v}\sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t) + d_i^{\,2}} + d_i.$$

Thus we obtain the dynamics equations of general view market model

$$\lambda_i x_i(t+1) = \sqrt{\frac{b}{v}w_i(t) + d_i^2} + d_i - w_i(t) \qquad (i = 1,\dots,n(t)), \tag{4}$$

where $\lambda_i = \lambda_i(t) = \sum_{j=1}^{n(t)} \delta_{ij}(t)$, $w_i(t) = \sum_{j=1}^{n(t)} \chi_{ij}(t)x_j(t)$, $d_i = d_i(t) = \frac{1}{2}\frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\lambda_i(t)$.

In this paper we consider all actions, expectations and strategies of firms in short-run period, therefore the equations parameters λ_i and d_i are assumed further as constants which are independent of time.

Let the market of homogeneous product consists of m firms' types, each type l including k_l identical firms: $l = 1,\dots,m,\ k_1 + \dots + k_m = n.$ Then $\lambda_i = \sum_{l=1}^{m} k_l\delta_{il}$, ,

$w_i(t) = \sum_{l=1}^{m} k_l\chi_{il}\cdot x_l(t)$, where $\delta_{il} = \delta_{ij}, \chi_{il} = \chi_{ij}, x_l(t) = x_j(t)$ at all j from type l. Then owing to (4) $x_i(t+1) = x_l(t+1)$ at all i from type l. As a result dynamics in the equations (4) has dimension m:

$$\lambda_i x_i(t+1) = \sqrt{\frac{b}{v}w_i(t) + d_i^2} + d_i - w_i(t) \qquad (i = 1,\dots,m), \tag{5}$$

where $\lambda_i = \sum_{l=1}^{m} k_l\delta_{il}$, $w_i(t) = \sum_{l=1}^{m} k_l\chi_{il}\cdot x_l(t)$, $d_i = \frac{1}{2}\frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\lambda_i$.

The equations (5) are a special case of (4) and simultaneously their generalization, i.e. they are equivalent to (4) in short-run period.

In particular, in two-dimensional model [17] ($m = 2$) for firm i

$$\lambda_i = \sum_{j=1}^{n} \delta_{ij} = 1 + p(k-1) = \lambda_x,\ \ w_i(t) = \sum_{j=1}^{n} \chi_{ij}x_j(t) = q(k-1)x(t) + (n-k)y(t) = w_x(t),$$

$$d_i = \frac{1}{2}\frac{b\Theta}{v}\frac{1-\alpha}{\alpha}\sum_{j=1}^{n} \delta_{ij} = \frac{1}{2}\frac{b\gamma}{vk}\frac{1-\alpha}{\alpha}(1 + p(k-1)) = d. \tag{6}$$

So for two-dimensional model [17] equations (5) have the form

$$\begin{cases} \lambda_x x(t+1) = \sqrt{\frac{b}{v} w_x + d^2} + d - w_x \\ \lambda_y y(t+1) = \sqrt{\frac{b}{v} w_y} - w_y \end{cases}, \qquad (7)$$

where $\lambda_x = 1 + p(k-1)$, $w_x = q(k-1)x(t) + (n-k)y(t)$, $\lambda_y = 1 + p(n-k-1)$,

$w_y = kx(t) + q(n-k-1)y(t)$, $\quad d = \frac{1}{2}\frac{1-\alpha}{\alpha}\frac{b\gamma}{vk}(1 + p(k-1))$.

We usually use further the following simplest after two-dimensional version of (5) for the illustrations of results of computational experiments. In this version we consider a market of three firms' types: k_1 and correspondingly k_2 reciprocator firms, ($k = k_1 + k_2$) and $dn = n - k$ identical selfish firms. Here as well as above $\alpha_1 = \alpha_2 = \alpha$, $\alpha_3 = 1, \delta_{13} = \delta_{23} = \delta_{31} = \delta_{32} = 0, \chi_{ij} = 1 - \delta_{ij}$. Then (5) has the form

$$\lambda_i x_i(t+1) = \sqrt{\frac{b}{v} w_i(t) + d_i^2} + d_i - w_i(t) \qquad (i = 1,2,3), \qquad (8)$$

where $\lambda_1 = 1 + \delta_{11}(k_1 - 1) + \delta_{12}k_2$, $\lambda_2 = 1 + \delta_{22}(k_2 - 1) + \delta_{21}k_1$, $\lambda_3 = 1 + \delta_{33}dn$,

$w_1(t) = \chi_{11}(k_1 - 1)x_1(t) + \chi_{12}k_2x_2(t) + dnx_3(t)$, $\quad w_2(t) = \chi_{22}(k_1 - 1)x_2(t) + dnx_3(t)$,

$w_3(t) = \chi_{33}(dn-1)x_3(t) + k_1x_1(t) + k_2x_2(t)$, $\quad d_i = \frac{1}{2}\frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\lambda_i$ $(i = 1,2)$, $d_3 = 0$.

2.2 Equilibrium Conditions

In a Nash equilibrium point we have $x_i(t+1) = x_i(t) = x_i$ at all $t = 1, 2, \ldots$ and $i = 1, \ldots, m$. Hence $x_i^e(t+1) = x_i$ at all i and t.

Proposition 1. There is unique Nash equilibrium point in a general market model (5).

Proof. In an equilibrium point $z_i = x_i(t+1) + \sum_{j \neq i} x_j^e(t) = \sum_{j=1}^{m} x_j = z$ at all $i = 1, \ldots, m$.

Therefore owing to (3)

$$z^2 = \frac{b}{v}\sum_{j=1}^{n}\chi_{ij}(t)x_j + \frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\sum_{j=1}^{n}\delta_{ij}z = \frac{b}{v}\sum_{l=1}^{m}k_l\chi_{il} \cdot x_l + \frac{b\Theta_i}{v}\frac{1-\alpha_i}{\alpha_i}\lambda_i z \ (i = 1, \ldots, m),$$

where $\lambda_i = \sum_{l=1}^{m} k_l \delta_{il}$, $x_l = x_i$ at all i from type l, $l = 1, \ldots, m$. Hence

$$\sum_{l=1}^{m} k_l \chi_{il} \cdot x_l = a_i \qquad (i = 1, \ldots, m), \qquad (9)$$

where $a_i = \frac{v}{b} z^2 - \frac{1-\alpha_i}{\alpha_i} \Theta_i \lambda_i z_i$. Since matrix of types parameters $(k_l \chi_{il})$ is nonsingular $m \times m$ matrix on construction then the system of linear equations (9) has one and only one solution, Q.E.D. .

For two-dimensional system (7) this Nash equilibrium point is the same, as in [17] and also is set by the same formula.

Proposition 2. There is unique Nash equilibrium point in a dynamical system (7):

$$y^* = \frac{\frac{b}{v}(kG + q(n-k-1))}{(kG + (n-k))^2} \qquad x^* = Gy^* = \frac{\frac{b}{v}(k + q(1/G)(n-k-1))}{(k + (1/G)(n-k))^2}, \qquad (10)$$

where function $G = G(p, q, n, k, \alpha) = \dfrac{p(n-k) + q(\alpha + (1-\alpha)\frac{n-k}{k})}{(2\alpha - 1)(1 + p(k-1))}$.

Proof. Since (6) equation (3) has the following form for any reciprocator firm i

$$z_i^2 = \frac{b}{v}(q(k-1)x(t) + (n-k)y(t)) + \frac{1}{2}\frac{1-\alpha}{\alpha}\frac{b\gamma}{vk}(1 + p(k-1))z_i. \qquad (11)$$

For any selfish firm equation (3) takes the form $z_i^2 = \frac{b}{v}(kx(t) + q(n-k-1)y(t))$. But in the Nash equilibrium point $x(t+1) = x(t) = x_i(t) = x$, $y(t+1) = y(t) = y_j(t) = y$ at all i, j and $t = 0,1,...$. Then since (11) we get

$$(kx + (n-k)y)^2 = \frac{b}{v}(k\,x + q(n-k-1)y) =$$

$$= \frac{b}{v}(q(k-1)x + (n-k)y) + \frac{1}{2}\frac{1-\alpha}{\alpha}\frac{b\gamma}{vk}(1 + p(k-1))z_i. \qquad (12)$$

From second equation (12) we obtain the response function

$$\frac{x}{y} = \frac{p(n-k) + q(\alpha + (1-\alpha)\frac{n-k}{k})}{(2\alpha - 1)(1 + p(k-1))} = G \ .$$

To calculate the coordinates of a fixed point, we substitute the expression of y through x in the first equation (12), Q.E.D. .

In (10) by the data we get $x^* > 0, y^* > 0$. In view of the following proposition 3 it also ensures nonsingularity of a matrix (9) in proposition 1.

3. Desktop Application *Model* for Computing Experiments

During our research we developed desktop application *Model* to support the research process using computational experiments with dynamic systems. The main purpose of the application is to provide the best service for research cycle: hypothesis $\rightarrow$ experiment $\rightarrow$ hypothesis. It’s impossible to realize new idea with new device immediately, at once after it appearance for natural experiments. However here we can do it using application window with the appropriate tools. The results of new experiment give rise to new ideas, which we can check immediately using new windows and so on. Therefore intensive researches with multidimensional dynamical systems during this work have demanded efforts for computational speedup of the application. The goal of *Model* is the highest possible support for research process.

Model is a C# application created on the basis of the graphical interface of the System.Drawing and System.Windows.Forms C# system libraries. All calculations related to the model are localized in the *calc* method, which makes it easy to modify the equations of the model or move to other models.

Model application additionally uses *Open Maple* to work with differential equations and 3D graphs. *Open Maple* is access interface to Maple computational core from various programming languages: C#, Java, Visual Basic etc. In addition to the above standard namespaces is also used the System.Runtime.InteropServices namespace, which allow us to make links to the Maple dynamic linking core library - maplec.dll.

The following figure demonstrates the main application window which automatically appears when you open it.

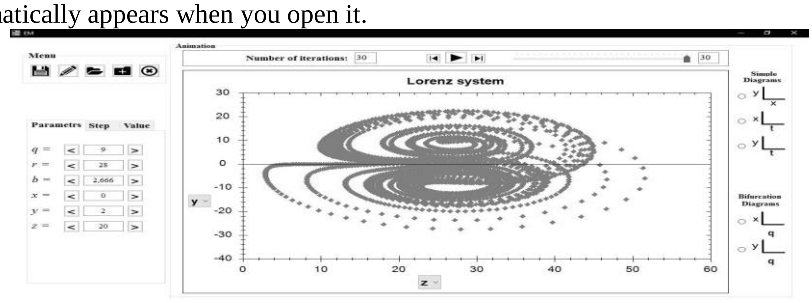

Fig. 1. Main window of the *Model* application

In the center of the window is located a two-dimensional projection of Lorentz system's attractor. In fig. 1 above in the left corner are the application menu buttons. From left to right: 1. *Save* button is used to save current model which is displayed on the screen with all the given parameters' values and settings under the chosen user name. 2. *Edit* button is used to modify the current model. 3. *Open* button demonstrates a list of saved models' names with the date of their last modification, which allows you to select and open a window of any of them. 4. *Add* button is served to define new models. 5. *Delete* button gives possibility to delete the current model (depicted on the screen) from the list.

The following fig. 2 shows the application window for market model of this paper.

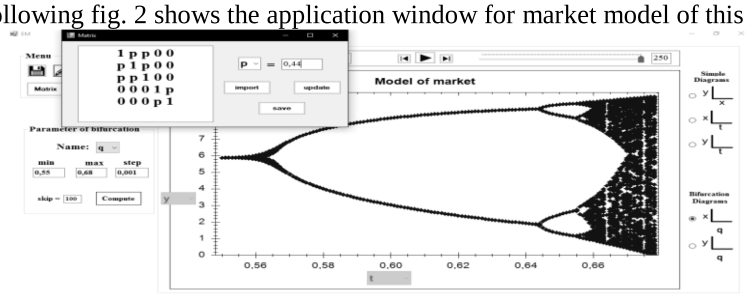

Fig. 2. *Model* application window for general view market model

On the right are 5 types of graphs, which are used most often; their examples are pointed out later in the paper. We can set model parameters and the initial values of the model trajectory using counters on the left. After these settings the graph of given model automatically appears in the center of the window. The number of iterations we can be set on the scroll bar above the graph. In the center of the window is also displayed the animation of the selected path when the button (near the scroll bar) is pressed.

When you click *Step* button on the left, you can set step of changing for a list of parameters. If you click *Value* button, you can obtain the table with coordinates of model trajectory for given iterations.

But the main tool to support computational investigations in *Model* application is easy modification of a current model after pressing of *Edit* button (fig. 3). Modification window is located over the current model window, which allows using both windows at the same time. After left click on the model equation in the field *The dynamical system* will move to the field *Equation*, where it can be changed. After pressing *Add* the modified equation will return back. Similar procedure can be done with parameters. We can also add new equations and parameters and delete the previous ones. In the field *System name* we can specify the name of the new model modification. After clicking *Save* button, new model falls into the saved list. If you click *Change*, the new modification will be saved under the name of the current model, which is deleted. When you click *Back*, the modification is temporarily suspended and we return to the current window. *View* button displays information about the model (equations, parameters and settings).

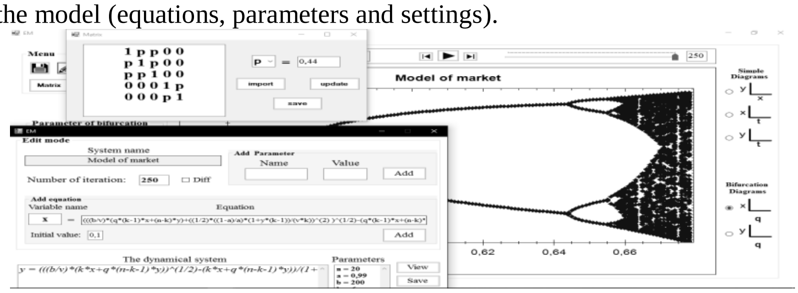

Fig. 3. *Model* application window for modifying the current model

4. Investigation of General View Market Model via Computing Experiments

4.1. Dependence of General View Market Model on Number of Firms

According to [18] with number of firms increase a market moves from stability to chaos. Whether so it for the model of this paper? Let in system (8) $k_1 = k_2 = 10$, $b = 200$, $v = 2$, $\alpha_1 = \alpha_2 = 0.99$, $\delta_{11} = \delta_{22} = \delta_{33} = 0.5$, $\delta_{12} = \delta_{21} = 0.12$, $\Theta_1 = \Theta_2 = 0.1$.

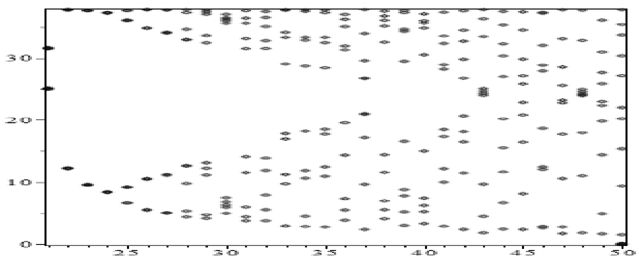

Fig. 4. The bifurcation diagram of dependence of quantity x_1 on n .

Here the horizontal axis represents the number of firms n from 20 to 50; the ordinate axis represents the quantity $x_1(t)$ of first reciprocator firm on attractor of the trajectory. The path has the equilibrium stable state at $n = 20$. However as we can see at $n = 21$ bifurcation occurred and instead of equilibrium point there is a stable cycle. There values of x_1 are approaching the point $x_1{*} \approx 40$ for even t and the point $x_1{*} \approx 10$ for odd t. By doubling the lag between iterations only even or only odd iterations will be considered, and thus either point $x_1{*} \approx 40$, or $x_1{*} \approx 10$ respectively would be the equilibrium stable state. Stable cycle has four points for $n = 25$ (fig. 4). There was a new cycle doubling (flip) bifurcation. Calculations show that with parameter n increase doubling bifurcations continue following Sharkovskii's order. At $n = 45$ there is a state of dynamic chaos (fig. 4).

Process of division of stable equilibrium on some directions will clear up, if during it we trace profit changes. *Model* tools allow us to demonstrate the dependence between reciprocator firm's profit π and number of firms n for the same parameter values that in bifurcation diagram 4 above.

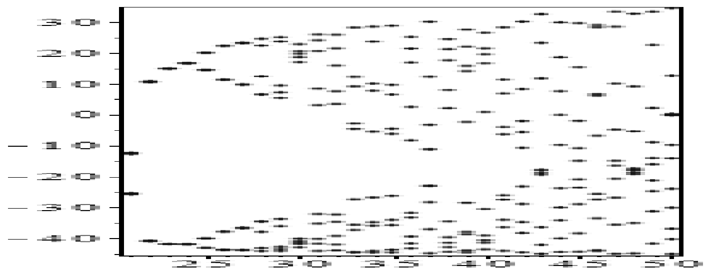

Fig. 5. The bifurcation diagram of dependence of profit π on the number of firms n.

It appears that the real choice here is unique and depends on quantity output. The smaller quantity output the bigger the firm's profit. Moreover, the profit for bigger output direction varies around zero and often converts into a loss. But quite unexpected is the effect well visible in a fig. 5: firm's profit in chaotic state is on average greater than in stable state. This example illustrates typical, many times investigated via *Model* behavior of dynamics of the general view market model with increasing number of firms.

Analysis of computing experiments for model (7) in [18] show, that such behavior arises provided that firms in the market are not identical, reciprocators and egoists are also presented enough there. How can we generalize such condition for the general view market?

Let in system (8) $\delta_{12} = \delta_{21} = 0.5$ instead of 0.12 above saving all other parameters. Then in (8) disappear difference between first and second types of reciprocators, they unite in one type. Such system has stable equilibrium at all n. By $\delta_{12} = \delta_{21} = 0.4$ the whole attractor is a cycle of an order 2 at all n. By $\delta_{12} = \delta_{21} = 0.2$ it is a cycle of an order 4 at all n. By $\delta_{12} = \delta_{21} = 0.14$ a state of dynamic chaos arises at $n = 140$. At $\delta_{12} = \delta_{21} = 0.12$ we return to fig. 4, where chaos arises by $n = 45$.

But the less value of $\delta_{12} = \delta_{21}$ the greater difference between types of reciprocators and so the market is more heterogeneous. All our computing experiments lead to the following conclusion. The more difference (segregation) between firms i.e. the more types of firms are in a market, the faster this market directs to complex dynamics and to chaos due to increase of firms' number.

4.2. The Crucial Factors which Ensure Stability in General View Market

Apparently the main assumption of the traditional neoclassical economics is the idea of automatic stabilization and market order due to increasing the number of independent firms and achievement of perfect competition. This is realization of Adam Smith's 'invisible hand' [19]. Then how stability is possible in real markets with the effects revealed in the previous section?

We found [17] that adaptive behavior is the main tool that ensures the stability of model (7). While increasing of number of firms directs a market to complex dynamics and finally to chaos the increase of adaptive expectations acts in an opposite direction. Due to increase of adaptive expectations predictability and stability of market becomes stronger; due to increase of naive expectations the market loses stability and chaos grows. Whether it is true for multidimensional model of this paper?

Let $k_1 = k_2 = 10$, $b = 200$, $v = 2$, $\alpha_1 = \alpha_2 = 0.99$, $\delta_{12} = \delta_{21} = 0.12$, $\Theta_1 = \Theta_2 = 0.1$, $\delta_{33} = 0.5$ as above. But now $n = 35$ and $q = \chi_{11} = 1 - \delta_{11} = \chi_{22} = 1 - \delta_{22}$ is a variable parameter of following bifurcation diagram. Here q is the parameter of share in output of a market planned under naive expectations.

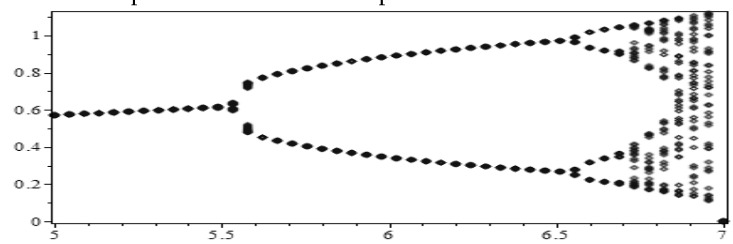

Fig. 6. The bifurcation diagram of dependence of quantity x_1 on q in the system (8).

Here the ordinate axis represents the quantity $x_1(t)$ of first reciprocator firm on attractor of the trajectory; the horizontal axis represents the parameter value of q multiplied by 10. This rescaling is done for the sake of clarity. In figure the same behavior that in [18]. And common sense prompts too, that increase of naive expectations conducts to chaos. However, in multidimensional model it is incorrectly to estimate a share of planning with naive expectations by the use of parameter $q = \chi_{11} = \chi_{22}$ of this example. Apparently we should estimate it by ratios of parameters δ_{ij} and χ_{ij} on all i and j. Formal definition will be given in section 4.4.

Computing experiments and common sense also testify that in multidimensional systems it is incorrectly to estimate adaptation only by the use of a share of planning with naive expectations. Let's consider an example. Let $k_1 = k_2 = 10$, $b = 200$, $v = 2$, $\alpha_1 = \alpha_2 = 0.99$, $\delta_{11} = \delta_{22} = \delta_{33} = 0.5$, $\delta_{12} = \delta_{21} = 0.2$, $\Theta_1 = \Theta_2 = 0.1$. At such values of parameters all trajectories of dynamical system (8) are drawn to stable equilibrium at all n. Let's now move away values δ_{11} and δ_{22} from their average 0.5 on quantity $\Delta = \delta_{11} - 0.5 = 0.5 - \delta_{22}$. Other parameters we save unchanged. Then at $0 \le \Delta \le 0.2$ the attractor consists of stable cycles. At $\Delta = 0.2$ there are cycles of an order 3.

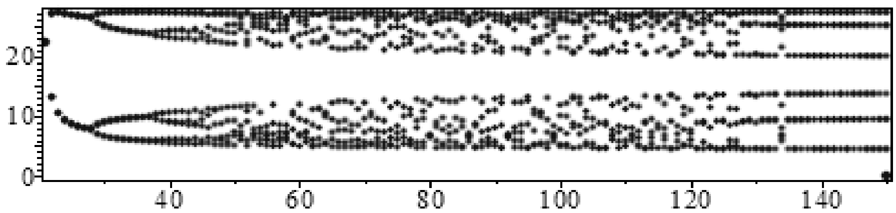

Fig. 7. The bifurcation diagram of dependence of quantity product x_1 on n at $\Delta = 0.2$.

Such order of a cycle means that there has already been passed all Sharkovskii's order of conditions and there is a dynamic chaos at $\Delta > 0.2$. We observe the similar trends if average of values δ_{11} and δ_{22} move away from δ_{33} or if δ_{12} move away from δ_{21}.

Numerous computing experiments and common sense testify that stability of the market critically depends on agreement of adaptive expectations of firms at planning. In particular, it depends on how close are all parameters δ_{ij} and respectively all χ_{ij}. In addition we note that condition in the end of section 4.1 is only a special case of this condition: the more types of firms in a market the lower there level of the agreement of adaptive expectations.

4.3. The Stability Factor of Market in Chaotic State

This part reveals the factor that ensures the stability of the market in a complex and even chaotic dynamics. If any type of firms increases their profit more quickly than their rivals then these firms will survive and expand their type among all firms [20].

In model (5) the ratio of profit of firm i from type l at period t $\pi_l(t) = (P(t) - v)x_i(t)$ to profit of firm j from type k $\pi_k(t) = (P(t) - v)x_j(t)$ at the same time period is:

$$\lambda_{lk}(t) = \frac{\pi_l(t)}{\pi_k(t)} = \frac{(P(t) - v)x_i(t)}{(P(t) - v)x_j(t)} = \frac{x_i(t)}{x_j(t)}.$$

This is the unexpected finding of our research [18] during computing experiments. In model (7) $\lambda_{lk}(t)$ is adiabatic invariant of a dynamical system, i.e. it is almost independent on t at $t > 2$ for all acceptable values of parameters. Direct generalization of this fact on model (5) proves to be true by all already made computational researches. For example consider the phase curve that corresponds to trajectory with dynamic chaos in fig. 4.

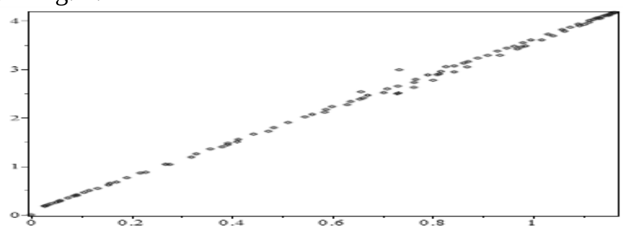

Fig. 8. Projection of phase curve of trajectory from fig. 4 at $n = 45$ to a plane x_1x_3.

The more chaotic dynamics, the more densely populated points on phase curve. But anyway it almost coincide with line segment, whose slope is equal to $\lambda_{lk}(t)$. We can suppose that rare small deviations from a straight line on fig. 8 are just technical failures at calculations. But look now on next fig. 9 with phase curve of trajectory of system (8) at parameters $n = 100$, $k_1 = k_2 = 10$, $b = 200$, $v = 2, \alpha_1 = \alpha_2 = 0.99, \delta_{11} = 0.68$, $\delta_{22} = 0.32, \delta_{33} = 0.5$, $\delta_{12} = \delta_{21} = 0.12, \Theta_1 = \Theta_2 = 0.1$.

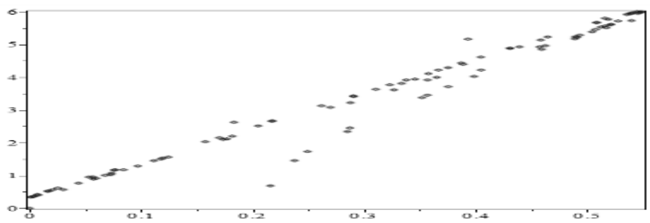

Fig. 9. Projection of phase curve with less level of agreement.

Here deviations from a straight line are already indisputable. The cause of difference from the previous example that here parameters $\delta_{11} = 0.68$ and $\delta_{22} = 0.32$ considerably deviate from their average $0.5 = \delta_{33}$. As it is noted in the previous section, it means reduction of level of agreement of adaptive expectations in the market, the key factor of stability in a market. All computing experiments show that if this level increases the value $\lambda_{lk}(t)$ comes nearer to a constant.

4.4. Universal Properties of General View Market Model

Let's formulate the formal statements which are clearing up derived results of computing researches. First of all let’s formalize the key concept of level of agreement in adaptive expectations in a market.

Let $x_{ik}^{e}(t+1)$ is quantity of firm k expected by a firm i, $Q_i^e(t+1)=\sum_{k=1}^{n} x_{ik}^e(t+1)$ is prospective industry output of a market expected by a firm i during next time period $t+1$. For firms i and j we put $\varepsilon_{ij}=\max_t \frac{\left|Q_i^e(t+1)-Q_j^e(t+1)\right|}{Q(t)}$, where $Q(t)$ is industry output of the market in period t. The value ε_{ij} characterizes disagreement in adaptive expectations of firms i and j. Value $\varepsilon=\max_{i,j}\varepsilon_{ij}$ we will call the level of disagreement in adaptive expectations in the market. Thus value $1-\varepsilon$ we will call the level of agreement in adaptive expectations in the market.

Proposition 3. The ratio of profits $\lambda_{lk}(t)$ is equal to a constant with accuracy $\pm 3\varepsilon$ at all $t>2$ for any fixed values of parameters of model (5).

Owing to this statement dynamics of a general view market model is stratified on dynamics of the local markets (7) from [17] with accuracy of the order ε. That is why all derived in [17], [18] and considered above properties of the local markets are generalized on the general view market of this paper. This fact explains universality of their properties. The formal reduction of following statements to results from [17], [18] is also based on this statement.

Let firm i suggests that production quantities of its rival j will be equal to $x_j^e(t+1)=\delta_{ij}(t)x_i(t+1)+\chi_{ij}(t)x_j(t)$ during next time period $t+1$, where $\delta_{ij}(t)\geq 0$ and $\chi_{ij}(t)\geq 0$, $i,j=1,...,n$. Then the value $\Lambda=\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\chi_{ij}}{\chi_{ij}+\delta_{ij}}$ we will call the share of planning with naive expectations and the value $1-\Lambda$ we will call the share of planning with adaptive expectations in the market. Thus $\Lambda=0$ if in the market there are no naive expectations, and $\Lambda=1$ at total using naive expectations for planning.

Proposition 4. At $\Lambda=0$ the unique Nash equilibrium of proposition 1 is stable for all possible values of parameters of a general view market model (5).

Proposition 5. At $\Lambda=1$ the unique Nash equilibrium of proposition 1 is unstable for sufficiently large number of firms n and all other acceptable values of parameters of model (5) if $\left|\frac{k_l}{n}\right|>3\varepsilon$ and $\left|\frac{k_l}{n}-\frac{3}{4}\right|>3\varepsilon$ for all types of firms $l=1,...,m$, where ε is the level of disagreement in adaptive expectations in the market.

Proposition 6. In a general view market model (5) flip bifurcations (cycle doubling bifurcations) occur following all Sharkovskii's order and finally chaos state occur with an increase of Λ from 0 to 1.

Proposition 7. In a general view market model (5) flip bifurcations occur and finally chaos state occur with an increase of number of firms in the market provided sufficiently large $\Lambda<1$.

As model (5) is equivalent to a general view market model (3) in short-run period, so actually propositions 3 – 7 describe universal properties of general view markets, including real markets as particular case.

5. Conclusion

Thus we have synthesized the heterogeneous agent-based model of general view market according to new economics paradigm as intersection of dynamic system theory, mathematical programming and game theory.

During our investigation we developed and continuously improved a desktop application *Model* for support the research process using computing experiments. As a result of simulation experiments via *Model* application we have revealed the following universal properties of general view market, including real markets. They are derived by generalization and specification of the basic properties of model [17].

The crucial factors which ensure the market stability are the level of agreement in adaptive expectations and the share of planning with adaptive expectations in a market. If no any firm use naive expectations in the market there is unique Nash equilibrium which is stable for all acceptable values of parameters. The increase of naive expectations leads to stability loss, to flip bifurcations and finally to chaos in general view market.

The increase of number of firms also leads to stability loss, to bifurcations and finally to chaos in the general view market at appreciable naive expectations. It appears that really the choice of equilibrium at these bifurcations is unique.

We revealed that the profits ratio and quantity outputs ratio of firms remains almost unchanged in short-run period in general view markets. It seems an important stability factor of many important real markets for which chaotic dynamics is usual.

In the further researches we plan to trace demonstrations of these universal properties on examples of real markets in details.

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Machine Learning in Estimating of SMEs Investment Potential in Ukraine

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Abstract. The aim of this research is to develop a model of SMEs investment potential assessment, using some of machine learning approaches. The structure of investment potential for SMEs was defined underlining their main characteristic features. It was revealed that the SME investment potential depends on factors of business environment measured by indicators of Annual Doing Business Reports developed by World Bank Group. The methodology for assessing the impact of business environment factors on the SMEs investment potential was developed. This methodology is based on the algorithm of machine learning, which can be used to design a model for forecasting the investment potential of SMEs. This model allows to determine the degree of influence of parameters on the formation of the SMEs investment potential. It is recommended to use computer language Python for optimization of time and human resources. It provides the opportunity to study the effects of the main drivers (both enhancement and reduction) of SMEs investment potential aimed at its improvement. The authors revealed that estimation results could become the basis for elaboration of recommendations regarding improvement of business environment in Ukraine.

Keywords: Machine learning, SME, Investment Potential, Business factors, Assessment model, Python

1 Introduction

The level of investment attractiveness plays the pivotal role for business development of every country. There are different types of ranking methodologies provided by international institutions covering various aspects of conditions for running business which objective results can help to observe the level of financial sustainability either to invest financial resources into a country`s economy or to abstain from it. Doing Business reports include economic indicators which can be used as information tool for identification of factors negatively or positively influencing investment attractiveness of economy and economic development on the whole.

Business environment factors as the elements of Doing Business methodology influence the investment potential of enterprises, small and medium sized (SMEs) in particular. Investment potential of legal entities defines the level of a separate country economic growth and its sustainability. That is why it is essential to assess the mentioned factors impact for investment potential formation and forecasting it which can be made by using Machine learning approaches.

In the research the effect of business environment factors on investment potential of small enterprises was defined by automatic relevance determination regression model. Besides, for medium ones it is reasonable to use classical linear regression for the mentioned purpose.

So, problems of investment potential growth and negative impact of different business factors need to be solved in order to minimize the business risk level, to increase the level of funding for enterprises, e.g. SMEs and to forecast the prospects of investment potential formation for SMEs.

2 Literature Review

The potential as a scientific category is universal in application. This allows it to be used in various fields of science: in biology, mathematics, physics, medicine and economics (particularly in investment). In economics investment, innovative, personnel, financial, technical potentials have been described in different literature studies. In this research investment potential of SMEs has been considered because it determines the directions of their activity at the investment market. It forms the grounds for further investment. Investment potential defines the axis, strategy, and performance of SMEs. Investment potential at the macro level shows potential volumes of attraction of financial resources to investment processes, revealing the contribution of SMEs to the country's economic growth. Permanent monitoring and measurement of the investment potential of SMEs allows their investment activity and their investment preferences to be tracked, and to determine the problems of feasibility of using resources for further investment.

There is a range of published studies describing the investment potential and approaches to its estimation, but in some scientific papers we can meet the term “investment opportunities”. In this study, we consider investment potential and investment opportunities as related categories. Previous research reflects the approaches which can be divided into several groups related to: (1) the resource, (2) market, (3) probabilistic, (4) resultative, (5) capacitive, (6) structural, (7) cost.

S. Leonov [1], J. Eklund [2], N. Yaremchuk [3] & P. Dieterlen [4] are proponents of the first group related to the resource which means that investment potential is considered as available resources of legal entities. Financial, material, technical and labor resources are the components of investment potential. The majority of supporters of this approach use value assessment of the mentioned types of resources for measuring investment potential. However, such costing method is quite rough, because the main focus is only on financial resources reflecting their cost measurement.

V. Shchelkunow [5] and C. Schulz [6], who are the market approach supporters, associate investment potential with the demand for goods and services. Demand can specify the volumes of investments for production, but it is essential to take into account resources of the enterprise.

K. Pokataeva [7] has considered the investment potential as probabilistic possibility of accumulation of the appropriate volume of resources for further investment by company. Although the researchers consider probability, they do not use the tools of probability theory.

T. Makukh [8] and T. Luehrman [9] in their works suggest the ability to achieve a certain return on the resources used (regardless of their type), or from the standpoint of assessing the economic results of current and future economic activity, the ability to generate investment income. This definition characterizes the resultative approach. Estimation of investment potential is very close to DCF-method (Discounted Cash Flow), but they are not similar and can produce different results. That is why assessment method due to this approach is considered to be understudied.

Complex approach for solving solving different types of information asymmetry problems between SMEs and other market participants aimed at simplifying investment and innovation processes in Ukraine for providing available useful information about the possible ways to attract financial resources was proposed by Yu. Sybirianska [22].

Capacitive approach revealed the ability of the subject of research (territory, enterprise, subsystem, etc.) "to absorb capital", which depends on several objective and subjective factors, and is described in papers such scientists as O. Shelest [10], O. Goralko [11], A. Kostonichenko [12] and J. Daggers & A. Nicholls [13]. Researchers face the problem of gathering data. Their approach has describable character and does not allow to evaluate the investment potential.

Previous studies did not consider all aspects of investment potential estimation. Moreover, these researches are based on old fashioned, weak methods of assessment and they demonstrate poor usage of statistical tools or probability theory. The considered methods are limited in using for assessment of investment potential on macro level, which can show the role and the place of SMEs investment activity. Research has been changing dramatically: the core focus is big data. These days the improved availability of data allows many investors (including SMEs) to make their decisions using instruments of machine learning (ML).

Nowadays, ML has changed the investment landscape, taking into account that ML and artificial intelligence may unleash new insights, like using data analysis before investing significantly in the technology.

In this study, we propose to use ML in SMEs investment potential estimation because it reveals the market structure, the effect of macro factors on SMEs, shows different drivers and losses of the economy due to technology changes and allows to assess business environment. For instance, making million transactions everyday ML can define where spending money is growing or prices are rising, effecting mostly consumers. This analysis can help consumers, policymakers and business representatives and other leaders make smarter decisions.

3 The Main Characteristics of SMEs Investment Potential Tendencies in Ukraine

Criteria for enterprise determination according to its size in Ukraine were changed by adding the new definition for microenterprises due to adoption of the Law on Development and State Support of Small and Medium Entrepreneurship in Ukraine in 2012 which amended the Commercial Code of Ukraine.

The State Statistics Services has started to generate data about the main indicators of business environment using these new criteria for enterprise definition since the mentioned date of law adoption.

Along with legislative changes such current urgent problems existed in Ukraine as conflict in the east of the country and long-term lack of key reforms, the economy stagnation and recession could be observed as the main constraints for creation and implementation of SME support policy.

Besides, the positive moments of business development within 2012-2016 include implementation of the key measures for business registration simplification, extension of e-government services, elimination of trade technical barriers, EU standards adoption and so on. On the other side, a lack of access to finance and real long-term strategy for SME could be considered as the debilitating force for business development.

Though the structure of business in Ukraine should be analyzed regarding such important indicators in dynamics as number of enterprises, their annual turnover and number of employees (fig. 1).

Analyzing fig. 1 it can be specified that in 2016 in total SMEs made up for more than 99 % of the legal entities in Ukraine. Overall, it is clear that while the growth rate of SME number fluctuated, the general trend was downward from 2,2 million entities in 2010 to 1,8 million entities.

In 2016, the private sector constitute in Ukraine was represented by 95,6 % of microenterprises, 2,6 % of small and almost 1 % of medium enterprises.

The chart from fig. 1 provides the dynamics of number of people employed in Ukraine within the period of 2010-2016, which decreased from 8,4 million people in 2010 to 6,5 million people in 2016. Negative growth rate of employed people for SMEs. is observed throughout almost all analyzed period of time

The share of SMEs in employment remained similar at approximately 77 %, herewith the share of medium enterprises for employed individuals was about 32 %. Therefore the significant imbalance can be observed as the share of medium enterprises is lower than 1 % of total legal entities in Ukraine.

Fig. 1 also shows the positive dynamics in turnover increasing in Ukraine within 2010-2016 with the growth rate about 87 % in 2016 compared to 2010. But the highest percentage has been marked for large and medium sized enterprises, equaling at about 30 % each.

Besides, it should be empathized that the share of large enterprises is less than 1 %, but the share of its annual turnover is 3 times higher than share of microenterprise turnover.

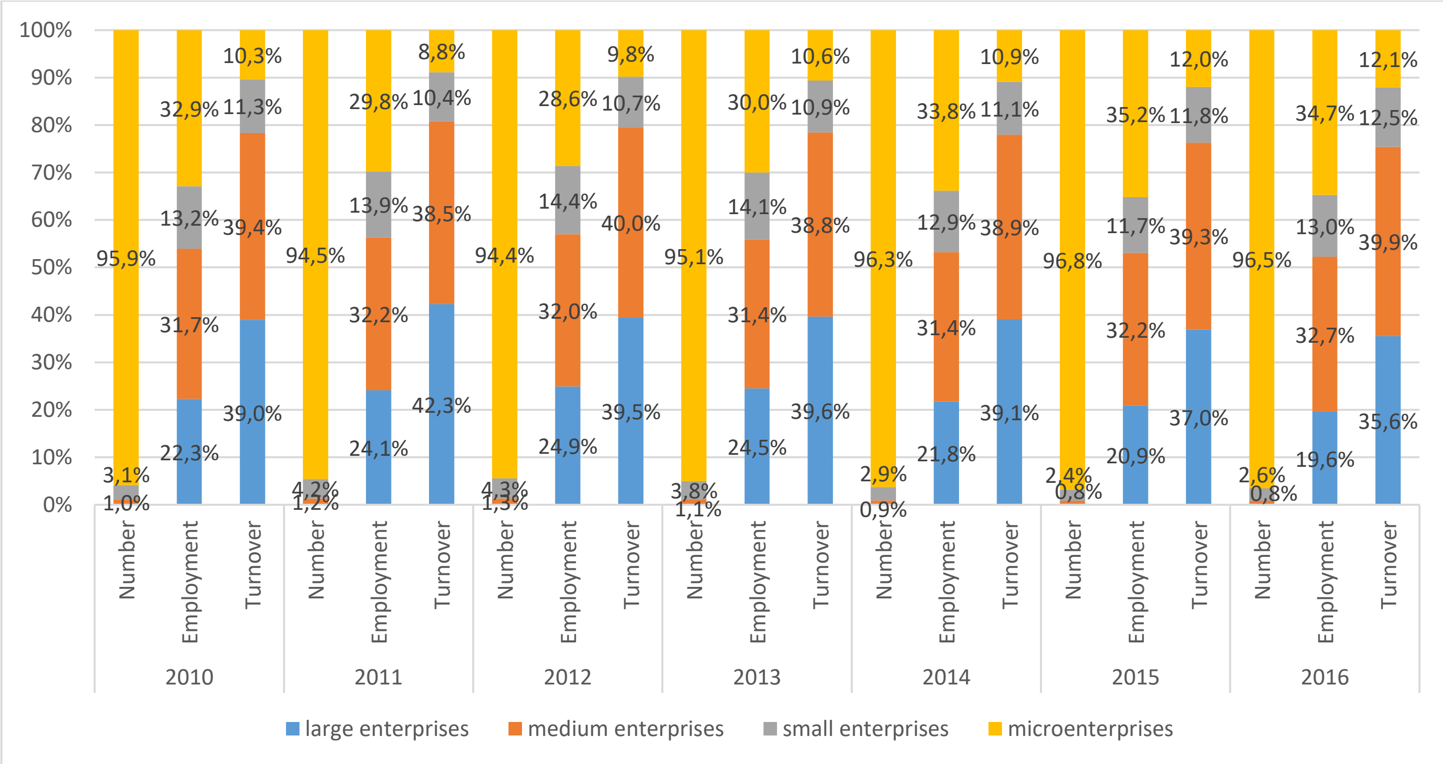

Fig. 1. General trend of business development in Ukraine within 2010-2016, % (Source: compiled by authors on the basis of [14])

To assess business development, it is reasonable to determine the investment potential of enterprises by determination of structure their equity and liabilities (fig. 2).

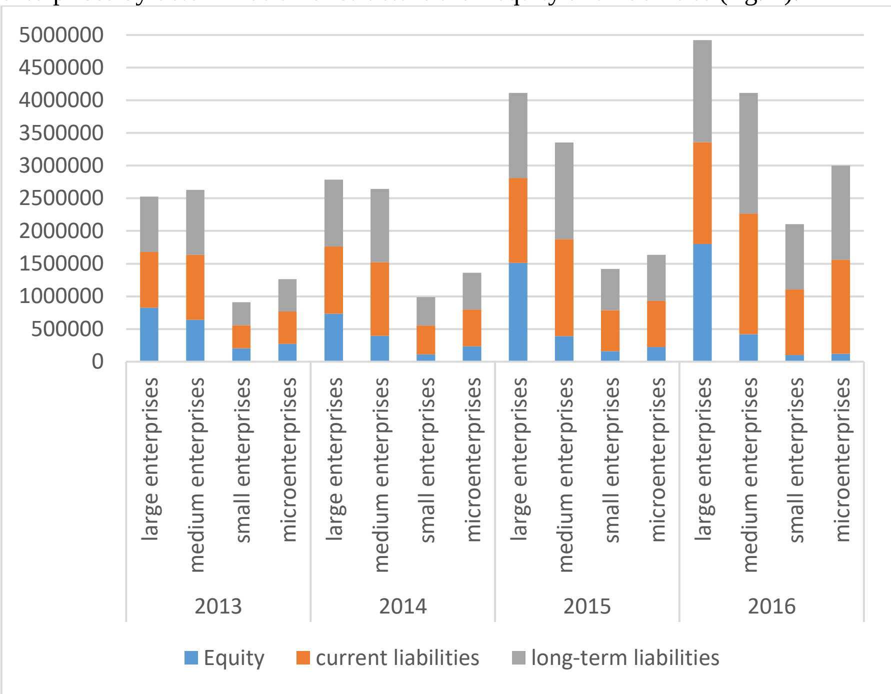

Fig. 2. Investment potential according to size of enterprise, thousands of hryvnas (Source: compiled by authors on the basis of [14])

Significant growth of capital can be observed for large and medium enterprises in 2016 in comparison with 2013 level, the growth rate equals 94,5 % and 54,6 % for each group respectively.

The investment potential of small and microenterprises is much less than for large and medium ones and mainly represented by current and long-term liabilities, the share of equity is too insignificant (about 4-5 %). In comparison with large and medium enterprises the level of equity sufficiency equals about 36,6 % and 10,2 % respectively.

Fig. 2 confirms that investment potential of SMEs is inefficient which proved by the structure of its liabilities which mainly represented by debt and not bank loans. That is why the level of provision by financial resources of SMEs is excessively low.

The next stage of analysis of SMEs investment potential tendencies is to determine the level of investment activity and its directions according to size of enterprises (fig. 3).

Fig. 3 demonstrates that the lowest level of investments is inherent to small and microenterprises, the main areas of which are investment to machinery and equipment.

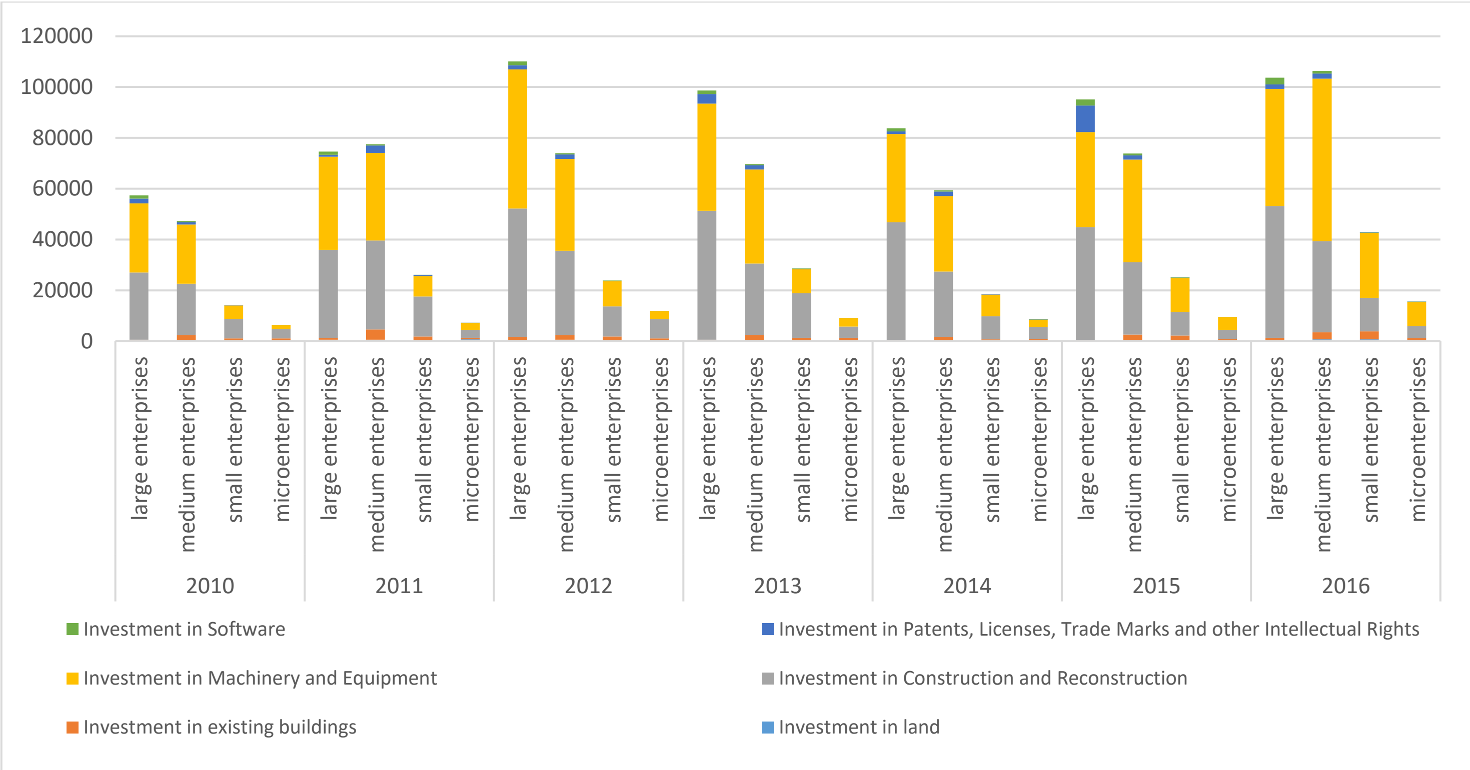

Fig. 3. Areas for investment according to size of enterprise, thousands of hryvnas (Source: compiled by authors on the basis of [14])

The amount of investment for large and medium enterprises is almost 3 times higher than for small ones, herein the main spheres of investment are investment in construction and reconstruction and machinery and equipment, that prove that financial resources are mainly directed to production.

Investment into software, patents, licenses and trademarks is not widespread for enterprises in Ukraine.

4 Doing Business Index as a Tool of Business Environment Assessment

As known, Global competitiveness index (GCI) is global research and the ranking of countries accompanying it in terms of economic competitiveness [21]. But due to the fact that the SME investment potential depends on factors of business environment measured by indicators of Annual Doing Business Reports developed by the World Bank Group it is advisable to consider the methodology of Doing Business rank. The methodology consists of 10 groups of factors with its indicators shown in table 1.

Table 1. The essence and factors of "Doing Business" rank methodology

Factor	The essence	Indicators
Starting a business	Identification of bureaucratic, legal constraints and costs required for entrepreneurs aimed at starting new business.	Procedure (number)
		Time (days)
		Cost (% of income per capita)
		Paid-in min capital (% of income)
Dealing with construction permits	Assessment of procedures, time and financial resources, connected with construction processes, obtaining permits and licenses, mandatory instruction, connection to utilities.	Procedures (number)
		Time (days)
		Cost (% of warehouse value)
		Building quality control index (0-15)
Getting electricity	Assessment of procedures, time and financial resources, connected with getting electricity.	Procedures (number)
		Time (days)
		Cost (% of income per capita)
		Reliability of supply and transparency of tariff index (0-8)
Registering property	Assessment of procedures, time and financial resources, connected with registration of property rights.	Procedures (number)
		Time (days)
		Cost (% of property value)
		Quality of the land administration index (0-30)
Getting credit	Assessment of credit bureau coverage of individual entrepreneurs and legal entities, and their collateral, which presupposes the estimation of factors which can simplify access to loans.	Strength of legal rights index (0-12)
		Depth of credit information index (0-8)
		Credit registry coverage (% of adults)
		Credit bureau (% of adults)

Factor	The essence	Indicators
Protecting minority investors	Assessment of protection level against illegal management of stock companies. Indices equal the sum of points for positive answers to relevant questions, e.g. one consent=one point.	Extent of conflict of interest regulation index (0-10)
		Extent of shareholder governance index (0-10)
Paying taxes	Assessment of taxes and mandatory contributions which should be paid by companies. The quality of tax administration and the level of tax burden are determined.	Payments (number per year)
		Time (hours per year)
		Total tax and contribution rate (% of profit)
		Postfiling index (0-100)
Trading across borders	Assessment of costs, including time, financial, which should be paid due to export or import of goods. 20—foot container is considered as typical situation.	Time to export: border compliance (hours)
		Cost to export: border compliance (USD)
		Time to export: documentary compliance (hours)
		Cost to export: documentary compliance (USD)
		Time to import: border compliance (hours)
		Cost to import: border compliance (USD)
		Time to import: documentary compliance (hours)
		Cost to import: documentary compliance (USD)
Enforcing contracts	Determination of the number of procedures, term and costs of company required to debt collection from unscrupulous buyer-legal entity, which refused to pay for delivered goods, citing its low quality in case when expertise confirms the sufficient level of goods quality.	Time (days)
		Cost (% of claim)
		Quality of juridical processes index (0-18)
Resolving insolvency	Determination of bureaucratic and legal constraints for an entrepreneur to overcome for company liquidation due to its bankruptcy and the main procedure and administrative bottlenecks of bankruptcy procedure. Assessment of set of company actions (terms, cost, the level of loan return) within bankruptcy procedure.	Recovery rate (cents on dollar)
		Time (years)
		Cost (% of estate)
		Outcome (0 as piecemeal sale and 1 as going concern)
		Strength of insolvency framework index (0-16)

Source: [15]

The rate is calculated on the basis of official statistical data and questionnaires of companies, requirements for which are described in table 2. The mentioned rank represents the integrated indicator, which consists of 10 sub-indicators in different categories, which are important for entrepreneur activity. The meaning of rank which is the closest to “top” position (1st rank in the list) shows better conditions for doing business than ranks close to 190 in the list [16].

The typical company for Doing Business assessment is Limited Liability Company located in the largest business center of country and 100 % domestically owned (more detailed analysis is given in table 2).

Table 2. Requirements to companies according to indicator of "Doing Business" rate

Indicator/ Requirements	Starting a business	Dealing with construction permits	Registering property	Getting credit	Paying taxes	Trading across borders	Resolving insolvency
Type of company – Limited Liability Company	+	+	+	+	+	+	+
City – the largest business center of country	+	+	+	+	+	+	+
Company 100 % domestically owned	+	+	+	+	+	+	+
Start-up capital equals	10 times income per capita	–	–	-	102 times income per capita	–	-
Company activity does not include foreign trade	+	–	–	–	– –	–	
Export volume of company	–	–	–	–	–	10 % from annual turnover	–
Company has real estate	+	–	–	–	–	–	–
Company has building	–	–	–	–	–	–	+
Company has land plot	–	+	–	–	+	–	–
Company staff	10–50 employees	60 employees	50 employees	Up to 50 employees	60 employees	-	201 employees & 50 suppliers
Annual turnover of company is not less	100 times income per capita	–	–	–	1,050 times income per capita	-	-

Source: [15]

Table 3. Ukraine in “Doing Business” reports within 2006-2016

Doing Business	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Position in rate	124	128▼	139▼	145▼	142▲	145▼	152▼	137▲	112▲	87▲	83▲
Starting a business	–	101	109▼	128▼	134▼	118▲	112▲	50▲	47▲	70▼	30▲
Dealing with construction permits	–	107	174▼	179▼	181▼	179▲	180▼	183▼	41▲	139▼	140▼
Getting electricity	–	–	–	–	–	–	169	166▲	172▼	138▲	137▲
Hiring	–	107	102▲	100▲	83▲	–	–	–	–	–	–
Registering property	–	133	138▼	140▼	141▼	164▼	166▼	149▲	97 ▲	64 ▲	61 ▲
Getting credit	–	65	68 ▼	28 ▲	30 ▼	32 ▼	24 ▲	23 ▲	13 ▲	17 ▼	19 ▼
Protecting minority investors	–	142	141▲	142▼	109▲	109▬	111▼	117▼	128▼	87▲	88▼
Paying taxes	–	174	177▼	180▼	181▼	181▬	181▬	165▲	164▲	106▲	107▼
Trading across borders	–	106	120▼	131▼	139▼	139▬	140▼	145▼	148▼	109▲	109▬
Enforcing contracts	–	26	46 ▼	49 ▼	43 ▲	43 ▬	44 ▼	42 ▲	45 ▼	98▼	98 ▬
Resolving insolvency	–	139	140▼	143▼	145▼	150▼	156▼	157▼	162▼	141▲	141▬

Source: [17]

The rates for Ukraine in “Doing Business” reports are presented in table 3, from which it can be seen the upward trend for Ukraine from 124 position in 2006 to 83 in 2016 demonstrates the positive dynamic reducing strong discontinuity. The positive changes are mainly connected with such indicators as “Starting a business”, “Registering property” and “Paying taxes”, but other indicators prove the set of complicated procedures for doing business in Ukraine.

The affirmative modifications relate to simplification of procedures of starting business, registering property and paying taxes exemplified as implementation of e-government services. All factors from table 1 and 3 have great impact for investment climate formation that is why they should be considered for designing the model for forecasting the investment potential of SMEs.

Advantages of Doing Business methodology like available big databases, different categories of parameters, possibility to overview risks and market potential, opportunity to make clear comparisons confirm the necessity to use data from Doing Business rank for designing the mentioned model.

5 Machine Learning Model of SMEs Investment Potential Estimating

The use of investment potential of SMEs is represented by allocating resources (liabilities) to assets [18]. Obviously, investment potential is formed by equity and liabilities, and its use by assets. Therefore, in the future, it is possible to use indicators of total volumes of equity and liabilities for analysis. For determining and analysis of the impact of business environment factors on SMEs it is advised to use such input data as investment potential of SMEs in different European countries (Slovenia, Czech Republic, Estonia, Slovakia, Hungary, Latvia, Poland and Ukraine) and their indicators of Doing business, mentioned above. We propose to use predictive models based on different methods: linear regression model and automatic relevance determination regression model.

The linear regression model is a type of modeling the ratio between the scalar y and the vector variable x. Like other regression analysis methods, linear regression represents the probability distribution of y depending on x rather than the distribution of the common probability y and x, which relates to the field of multivariate analysis.

In general, the linear regression model (one of the algorithms of ML) is defined as follows:

$$y = \beta_0 + \beta_1 x_1 + ... + \beta_k x_k + u, \tag{1}$$

where y is a dependent explanatory variable, (x1, x2, ..., xk) is an independent explanatory variable, u is a random error, the distribution of which in the general case depends on independent variables, but whose mathematical expectation is zero [18]. The dependent variable in our case is the value of the investment potential of the SMEs. Independent explanatory variables in this paper are indices of business environment factors: x1 – starting a business, x2 - dealing with construction permits, x3 - registering property, x4 - getting credit, x5 – protecting minority investors, x6 – paying taxes, x7 - trading across borders, x8 - enforcing contracts, x9 - resolving insolvency,

According to this model, the mathematical expectation of a dependent variable is a linear function of independent variables:

$$\mathrm{E}(y) = \beta_0 + \beta_1 x_1 + ... + \beta_k x_k + u. \tag{2}$$

The vector of parameters $(\beta_0, \beta_1, ... \beta_k)$ is unknown and the problem of linear regression is to evaluate these parameters based on some experimental values yi (x1, x2,…xk). For some n experiments, there are known values $\{y_i, x_{i1}, ..., x_{ip}\}_{i=1}^{n}$

of independent variables and the corresponding value of the dependent variable. According to the model definition for each experimental case, the dependence between the variables is determined by the formulae:

$$y_i = \beta_0 + \beta_1 x_{1,i} + \ldots + \beta_k x_{k,i} + u_i,$$

or in matrix notation: $y = x\beta + u$,
where

$$X = \begin{pmatrix} x_1' \\ x_2' \\ \vdots \\ x_n' \end{pmatrix} = \begin{pmatrix} 1 & x_{11} & \cdots & x_{1K} \\ 1 & x_{21} & \cdots & x_{2K} \\ \vdots & \ddots & \vdots & \\ 1 & x_{n1} & \cdots & x_{nK} \end{pmatrix}, \quad \beta = \begin{pmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_K \end{pmatrix}, \quad u = \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{pmatrix}. \tag{3}$$

On the basis of these data, the value of the parameters $(\beta_0, \beta_1, \ldots, \beta_k)$, is to be estimated as well as the distribution of a random variable [18]. These models are chosen because of their capacity to give the result of the analysis with the slightest error. For a specific group of enterprises (small or medium sized), the experimental way was to determine its model for predicting data.

These models are also implemented in the library of machine learning SCIKIT-learn. In addition, this library contains methods for evaluating the obtained results, which are used in the analysis of the impact of business environment factors on the development of the SMEs. These include: Mean absolute error, Mean squared error, and R^2 (R^2 score, the coefficient of determination).

For accurate analysis, it is necessary to normalize the entire amount of data that include equity and liabilities. Normalization is the process of analyzing ratios in order to identify and eliminate abnormalities of modification. These anomalies can be eliminated by splitting the initial relation into two or more new relations. The elimination of anomalies is carried out according to the following formula:

$$Y_{norm} = \frac{Y - Y_{\min}}{Y_{\max} - Y_{\min}}, \tag{4}$$

where Ynorm is the normalized value, Y is the actual value, Ymin is the minimum value for the total volume of data, Ymax is the maximum value from the total amount of data.

By choosing models to analyze the investment potential of different SMEs, each of them (model) needs to be trained for a variety of data: first by training (to generate coefficients of variables), and then - testing. Whereas, data processing is time-consuming and is to be optimized. The algorithm not only accelerated the process of data processing, but could also make such a methodology suitable for analyzing the impact of business environment factors on SMEs. The methodology was formed by the Python programming language.

Thus, the developed models made it possible to determine the influence of factors of the business environment on the SMEs investment potential. This technique allows to assess the factors which increase their investment potential, and which reduce it. The

evaluation results may form the recommendations basis for improving the business environment that affects the activities of its actors, including SMEs.
In general, this allows to consider the factors which affect the development of SMEs, outlining the main areas of creation, support and improvement of factors of the business environment that determine the activities of SMEs.

This shows the best results of the forecast (the lowest error (app. 0.02) and the highest communication factor (R^2=0.72) between the test and forecast figures). Data, obtained from official sites of the Organization for Economic Development and Cooperation, national regulators of the countries, used, have been normalized by the formula (4). Analysis of the impact of the 9 business environment factors on SME investment potential was made by using the SCIKIT-learn computer library and the Python programming language [19, 20].

Thus, the influence of factors of the business environment on the formation and use of investment potential of small businesses best describes the model of determination of regression with automatic determination of relevancy for small sized enterprises, while classical linear regression - investment potential of medium businesses.

In the learning process the prediction models and the coefficients of the equation were obtained, the absolute value of the module which characterizes the degree of influence on the investment potential, and their sign indicates the nature of the effect ("+" - increases the potential, "-" - reduces the potential).

The results of the modelling (table 4) show that such factors as starting business, protecting minority investors, paying taxes, enforcing contracts (because their coefficients have positive sign) increase investment potential both of small and medium businesses. The value of coefficient demonstrates the impact strength. The most crucial factor in forming the investment potential of small business is starting business (6.09e+05), while for medium businesses investment potential is paying taxes (6.3e+08). Paying taxes also plays a significant role due to the value of its indicator (4.98e+00) for small enterprises, starting business has almost the same value for medium sized enterprises (4.06e+01). Enforcing contracts also positively influences both small and medium businesses and their values are close to each other (2.14e+00 and 2.64e+00). The least positive impact on formation of SMEs investment potential is made by enforcing contracts factor.

Conversely, there is set of factors which reduce the investment potential of SMEs (in the models they have negative sign). Resolving insolvency (-9.94e-07 and -9.70e+00) and getting credit (-8.19e+03 and -8.44 e +04) are among the most destructive factors which sway on formation of SMEs investment potential. This fact proves poor performance with low level of banking SMEs loaning. One more common influence but in different degree (for small businesses - (-1.81e-03) and for medium enterprises - (-5.91e+00)) is trading across the borders. Table 4 shows that for medium sized businesses export opportunities are result forming. In the case of export strategy absence, the activity of medium enterprises remains in the lowest. Inability to export inhibits the competitiveness of medium enterprises of Ukraine in the global business environment.

Although most factors are common for all types of SMEs, at the same time models help to observe some dissimilarities.

Table 4. Specification of models for forecasting the investment potential of small and medium enterprises*

Indicators of business environment factors	**Designation of factors in the formula**	**Designation of factors in the program code**	**The degree of influence of business environment factors on small enterprises investment potential (automatic relevance determination regression model):** Y_{SE}=(6.09e+05)*X1+(3.05e-01)*X2+(4.0.e+00)*X3+(-8.19e+03)*X4+(0.25e-03)*X5+(4.98e+00)*X6 + (-1.81e-03)*X7+(2.14e+00)*X8+(-9.94e-07)*X9 **(1)**		**The degree of influence of business environment factors on medium-sized enterprises investment potential (classical linear regression):** Y_{ME}= (4.06e+01)*X1 + (-7.48e+00)*X2 + (-1.39e-+01)*X3+(-8.44 e +04)*X4 + (2.44e-01)*X5+ (6.3e+08)*X6+ (-5.91e+00)*X7+ (2.64e+00)*X8+ (-9.70e+00)*X9 **(2)**	
			Increasing (0;+∞)	*Decreasing (-∞;0)*	*Increasing (0;+∞)*	*Decreasing (-∞;0)*
Starting a business	X_1	S_B	6.09e+05	…	4.06e+01	
Dealing with construction permits	X_2	D_C	3.05e-01	…	…	-7.48e+00
Registering property	X_3	R_P	4.07.e+00	…	…	-1.39e-+01
Getting credit	X_4	G_K	…	-8.19e+03	…	-8.44 e +04
Protecting minority investors	X_5	P_MI	0.25e-03	…	2.44e-01	…
Paying taxes	X_6	P_T	4.98e+00	…	6.3e+08	…
Trading across borders	X_7	T_B	…	-1.81e-03		-5.91e+00
Enforcing contracts	X_8	E_C	2.14e+00	…	2.64e+00	…
Resolving insolvency	X_9	R_I	…	-9.94e-07	…	-9.70e+00

**Designed by authors*

Thus, dealing with construction permits benefits investment potential of small enterprises (3.05e-01), whereas this factor has negative influence on the same indicator of medium businesses (-7.48e+00). The next distinguishing factor is registering property: in the case of small enterprises the result of registering property has positive influence on investment potential (4.07.e+00), while, medium businesses experience the negative impact (-1.39e-+01).

Therefore, the influence of business environment can differ for small and medium enterprises, confirmed by the fact that state and strategy policy for small and medium business should be different.

6 Conclusions

Investment potential of SMEs can be estimated with the help of ML tools, exemplified as developed models for small and medium-sized enterprises assessment in particular. These models allow to determine which factors of business environment have impact on investment potential of SMEs. The decisive feature of these models is not only to forecast investment potential but also to measure the degree of influence of each considered factor.

The results of the assessment can be used by policymakers and public authorities paying attention to policy directions constraining business development of SMEs. Getting credits should be supported by government in different ways (by monetary policy with decreasing interest rate, or its return to the SMEs; by tax policy with incentives for those SMEs which have credit pressure; developing non-banking funding etc.). According to the results resolving insolvency also reduces the investment potential of both small and medium-sized enterprises. The required changes in legislation should protect both creditors as well as bankruptcy enterprises from raiders.

The mentioned models can also help to identify the strengths and weaknesses of SMEs activity. The calculated investment potential should be used in processes of strategy formation, which determines the axis and performance of SMEs. Foreign investors can consider these results in decision making for investment financial resources into some economy or abstaining from it.

Statistical authorities also have to measure the indicators of the SMEs investment potential and its elements and Doing business indicators more often (with 4-time per year frequency). This will allow to make more precise forecasting and smarter decision-making.

These prediction models can be used for evaluation of investment potential of SMEs not only in Ukraine, but also in countries like Slovenia, Czech Republic, Estonia, Slovakia, Hungary, Latvia, Poland, because they have some similar conditions for running business.

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Computerized Intelligent System for Remote Diagnostics of Level Sensors in the Floating Dock Ballast Complexes

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Abstract. In this work the development of a specialized computerized system for remote diagnostics of level sensors of floating dock ballast system is presented. Ballast system of floating dock and requirements for reliable measurement of liquid levels in ballast tanks are described in detail. The hierarchical functional structure of the proposed remote diagnostic system consists of a multiprocessor computing complex with the corresponding software and the branched structure of digital devices. The authors propose the method of checking the correctness of level sensors that generally increases system reliability. The diagnostic calculations of the measurements correctness of the level sensors are performed on the basis of programmable logic device (PLD) with the Field-Programmable Gate Array (FPGA) architecture. The collection of diagnostic information from PLD is processed by a single-board computer that transmits data via the Internet to the cloud service “ThingSpeak”. The overall results of work of the remote diagnostics system for level sensors are displayed graphically in real time on any, specialized for these tasks, computer or mobile device that has Internet access.

Keywords: diagnostics; cloud service; modeling; FPGA; liquids level measurement, single-board computer.

1 Introduction

The floating dock is a complex technical construction mainly intended for performance of docking operations of immersion and emersion with the vessel and without it. Though in some cases the specialized floating dock is used as a platform for vessels’ transportation on shallow ways [1, 2].

Among the complex of floating docks systems the ballast system is the main one to perform docking operations, because the processes of filling and emptying of the ballast tanks lead to changes in the floating docks draft. Another important function for ballast system is eliminating of critical deformation of the floating dock and unwanted inclinations due to distribution of liquid ballast among the ballast tanks.

Moreover, the tanks of a dock are a part of the volume durable body in pontoons or towers, separated by watertight partitions from another volume. The correct ballasting and reliable level control of the ballast compartments guarantee the safe operation of floating dock.

Calculation of ballast system needs to be carried out for set time on the natural flooding of the floating dock. The pressure head of the outboard water coming into the dock is constantly changing. It is impossible to obtain the same resistance of the pipeline from any outlet valve or damper to any ballast tank without excessive complication of the valves. Accordingly, levels of water in ballast tanks at different time intervals may be differ from the given values. So, the calculation is carried out at the time of filling the most distant tank from the receiving hole.

This circumstance in case of simplification of the diagram and valves complicates operation of computer control system software and the Dockmaster-operator. For uniform filling of the dock it is necessary to manipulate gate valves, accelerating, decelerating water inflows in this or that tank depending on water level indices in tanks.

Operational control of ballast compartments' parameters with high precision and timely control of ballast supply for dock operations performing as well as ensuring of the absence of dangerous inclinations and large deflection is a complex problem.

Consequently, the problem of efficient operation of complex technical objects, which includes a floating dock, arises in the field of precise and reliable measurement. So, solutions of tasks of sensors' choice and their technical diagnostics should be obtained along with automation of floating dock. The questions of parameters measuring and calculating of the floating dock in one way or another are considered in a number of scientific papers [2-4], [9]. So, the systems of measurement and control of floating docks' parameters are developed using sensors, which are based on different principles of action. In particular, the sensors, that are based on pulsed reflection method and have a single electronic and structural design are used for determination of liquid level parameters of the floating dock [3]. The disadvantage of such solution is the significant mass-size indicators and specialized pipes that have the ability to contaminate. In addition, radar-type sensors find an application for liquid level measurement in ballast compartments [2]. Some sensors allow to measure the level with high accuracy (up to 1 mm). In addition, the accuracy and stability of measurements don't depend on the effect of destabilizing factors (temperature of the medium, evaporation and dust in the tank, the aggressive nature of the controlled product, etc.) when using radar sensors. However, this method has a high cost service of automation level control systems due to the periodic carrying out of preventive checks of the radar sensors normalcy. Also membrane type sensors [9], in which the deflection of membranes under the pressure of a water column is converted into the resistance of the electrical circuit, are used. Such sensors have flaws related to the sensitivity to frost, which may cause a failure of measurement accuracy.

Today measurement and control of parameters of technological processes of floating docks are carried out using SCADA (Supervisory Control and Data Acquisition) systems regardless the sensor types. Using of SCADA systems allows collecting information about technological process, provide an interface with operator, accumulate database and implement automatic control of the executive mechanisms. An important feature of SCADA-systems is the question of controlling the reliability of the process and emergencies prevention. In the case of non-complicated technical diagnosis, you can restrict the standard capabilities of commonly used SCADA systems. Operations with events, analog and digital alarms should be related to standard diagnostic testing capabilities of SCADA systems [5-10]. SCADA-systems are complemented by additional software, hardware and diagnostic equipment to implement more complex technical diagnostics.

Particular attention deserves the approaches of technical diagnostics of industrial information control systems based on programmable logic. The development of control and diagnostic equipment of various applications based on PLD with FPGA architecture is considered in a number of papers [11-13]. Active FPGAs are implemented to provide information safety and cyber security of information and control systems for nuclear power plants [11]. In work [12] the method of self-testing of digital circuits at the enterprise of their manufacture is considered, where in the given circuits at the time of production control the necessary diagnostic support is installed. Also, FPGA technology for technical diagnostics found its application in radio communication with the transmission of information at a distance along the radio [13].

Thus, the issue of designing of effective high-precision computerized systems for controlling parameters of the floating dock with the use of diagnostic equipment, software and hardware remains open. Using new types of sensors and modern principles of constructing of distributed control systems based on SCADA software systems will give the opportunity to solve this problem, create a universal highly effective computerized control system, and control the parameters of the floating dock.

2 Functional Structure of Computerized System for Monitoring and Control of Ballast System Parameters of Floating Dock

The ballast system of the floating dock can have a linear or circular pattern in keeping with the design and carrying capacity of the floating dock. In the linear scheme the pumps are arranged on one board of the floating dummy pontoon and connected to the distribution box, which distributes the processes with the corresponding gate valves to the ballast compartments. In turn, the distribution boxes are connected by linear pipelines with gate valves. The linear scheme provides pumping of water by the pump of the neighboring distribution box at the emergency failure of any of the pumps. The circular circuit consists of two board masters, connected by at least two jumpers. The main line combines ballast pumps and ballast compartments with spindle shutters. At the event of failure of part of the pumps on the ring system, such a system allows to pump water from any compartment by other pumps.

Regardless of the ballast system, the general view of the location of ballast compartments on a number of floating docks is shown in the Fig 1. From the drawings one can see that the ballast tanks of large capacity BT13-BT18 are located in the central part of the dock, and ballast tanks of small capacity BT1-BT12 - in the bow and stern.

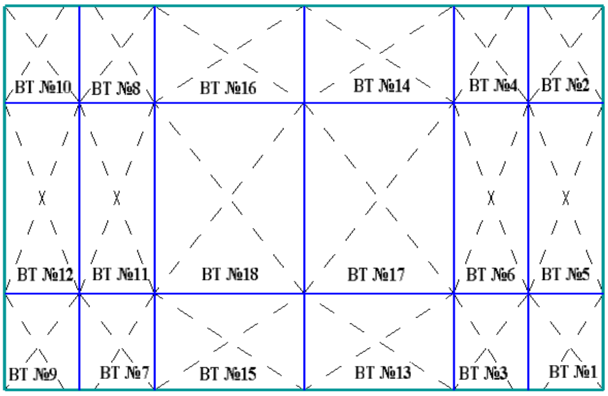

Fig. 1. The layout of the ballast tanks

The authors developed a special multifunctional computerized system based on the remote monitoring and control principles using multiprocessor devices and SCADA software [8] for control of level and physical parameters of liquid products in ballast floating docs. This system is built on a modular (variable-configuration) structure and has a separate distinct system of remote technical diagnostics using cloud-based ThingSpeak technology.

The functional structure of intellectual computerized system of monitoring and control of fluid level is shown in Fig. 2.

Each tank of the floating dock is equipped with pressure sensor PS, three temperature sensors TS, one discrete level sensor DLS (or float level switch), hydrostatic pressure sensor HPS and an input IV and output OV valve.

Level sensors and temperature sensors are used to obtain information of current level L and water temperature T in ballast tanks. A discrete level sensor is required for fixing a certain level value. The pressure sensor PS serves to determine the presence of excess pressure P inside the tanks.

Output signals from sensors are transmitted to the data acquisition module (DAM), which transforms analog signals to the corresponding digits that are transmitted to the PLC (Programmable Logic Controller). The PLC contains a program unit for calculating the dataset parameters, a program unit for liquid volume calculation, and a program control unit for valves. All of them are implemented using specialized SCADA TRACE MODE software [9]. The information about current values of the liquid level L in each ballast tank of the floating dock is displayed on the operator's computer screen (OTS) using a specialized human-machine interface.

The human-machine interface allows operator to control input and output valves for filling and emptying the ballast tanks by controlling the flow Q. Control signals arriving from the OTS are processed in the program control unit for valves and sent to the discrete output module (DOM). In turn, DOM implements the distribution of discrete signals which mean opening and closing of IV and OV.

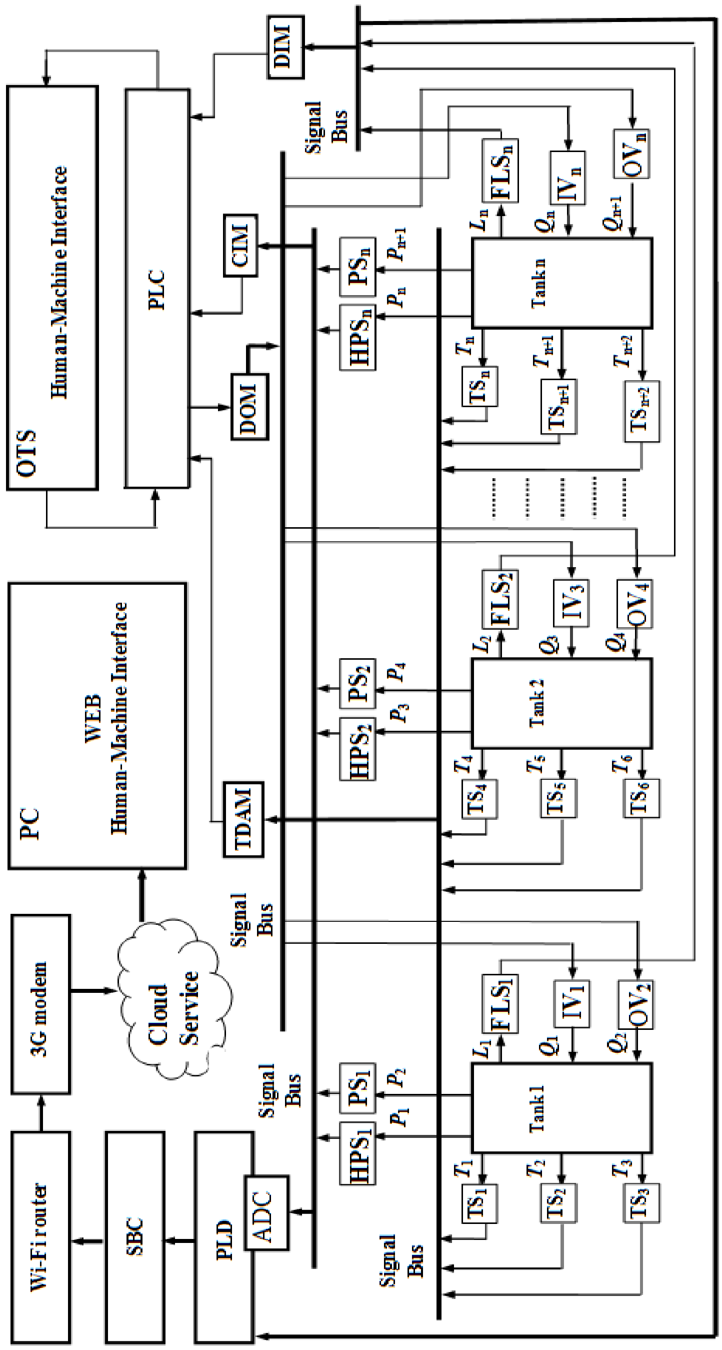

Fig. 2. The functional structure of intellectual computerized system of monitoring and control of fluid level.

This computerized system of monitoring and control of ballast tanks' parameters is also equipped with a computerized intelligent system for remote diagnostics of level sensors. The diagnostic equipment should include discrete level sensors, PLD along with an analog digital converter ADC, single-board computer, WiFi router, 4G modem and ThingSpeak cloud service.

Data from hydrostatic and discrete sensors processed using a programmable logic device PLD with FPGA architecture, which, according a specific VHDL models, determines state of the hydrostatic and discrete sensor. To the diagnostic computing equipment should include the PLD, a single-board computer, WiFi router, 4G modem, cloud service ThingSpeak. Diagnostic information from PLD processed by a single-board computer that transmits data through Internet network to the ThingSpeak cloud service. Moreover, the Internet on a floating dock is provided by a 4 G modem with the help of global wireless mobile technology 4G (data transfer rate up to 1 Gbit / s) and distributed on the floating dock premises using a WiFi router and additional WiFi access points. The general results of the remote diagnostic system for level sensors are displayed in the ThingSpeak graphically in real time on any computer or mobile device that specialized for these tasks and had access to the Internet.

3 Technical Diagnostics of Level Sensors in the Floating Dock Ballast Complexes

The integrated automation of the floating dock and a large number of sensors is associated with an increased likelihood disturbance of the normal operation mode for automatic control system for filling and emptying of ballast tanks. An effective way to increase the reliability of the automatic control system is the diagnostic procedures of system elements, in particular level sensors.

Diagnosis is the control of level sensors state in order to detect and prevent failures. The diagnostics is carried out using diagnostic tools that can be embedded and external. Built-in tools allow the continuous monitoring. The periodic control is implemented using external means. In our case, a second approach is used in which the state of the sensors is checked at discrete time intervals.

The technical condition of the each sensor for level measuring is characterized by the factors, under the influence of sensor it changes in time, these include the effects of climate conditions, aging with time, regulation of mechanical and electronic components, adjustment during maintenance or repair, etc [14-18].

The sensors for level measuring can operate in different technical conditions. The conditions can be as follows:

1) operative condition - the condition of the sensor, in which the value of all parameters that characterize the ability to perform the specified functions of the sensor, corresponds the requirements of normative as well as technical and (or) design documentation;

2) fault condition - the condition of the sensor, in which the value of at least one parameter does not correspond the requirements of normative as well as technical and design documentation.

3) limit condition - the condition in which further exploitation of an object is inadmissible or inexpedient, or the restoration of the state is impossible or inappropriate.

The statistical estimation of probability of failure-free operation of sensors can be obtained as a result of studies on reliability.

To study N objects to refuse the last object, use the formula:

$$P(t) = \frac{N(t)}{N} = \frac{N - n(t)}{N} = 1 - \frac{n(t)}{N}, \tag{1}$$

where N is the number of sensors, in the course of research; $N(t)$ is the number of working sensors at the time t, $n(t)$ is the number of sensors that stopped working at time t from the beginning of the research.

Often it is necessary to determine the probability of error-free operation of the sensor in the interval of time from t_1 to t_2, which represents the conditional probability that the sensor will not refuse this interval if it has worked without fail until the start of the interval.

Then a static estimate of the probability of failure-free operation:

$$P(t_1, t_2) = \frac{N(t_2)}{N(t_1)} = \frac{N - n(t_2)}{N - n(t_1)}, \tag{2}$$

where $N(t_1)$, $N(t_2)$ is the number of robotic sensors, respectively, at the beginning and at the end of the time interval, $n(t_1)$, $n(t_2)$ is the number of failed sensors, respectively, at the beginning and at the end of the time interval.

The probability of a failure $Q(t)$ is the probability that within the given outputs of the object rejected at least once.

Statistical estimation of the probability of failure in time or work:

$$Q(t) = \frac{N - N(t)}{N} = \frac{n(t)}{N}. \tag{3}$$

Operative and fault conditions are opposite incompatible conditions that create complete possible group of states of sensors in any time or for any developments.

$$P(\mathrm{t}) + \mathrm{Q}(\mathrm{t}) = 1. \tag{4}$$

If $P(t=0)=1$, then $Q(t=0)=0$; if $P(t=\infty)=0$, then $Q(t=\infty)=1$;

The probability of failure operations and the probability of failure - dimensionless magnitudes expressed in parts of the unit, sometimes in percent.

The sensitivity of the diagnostic parameter characterized by the ratio:

$$r = \frac{D_{npi} - D_{ni}}{S_{npi} - S_{ni}} = \frac{\Delta D}{\Delta S}, \tag{5}$$

where D_{npi}, D_{ni} – the nominal and limiting value of the diagnostic parameter; S_{npi}, S_{ni} – the nominal and limiting value of the structural parameter.

For the proposed method of technical diagnostics in the working space of the ballast tank two level sensors are installed at an appropriate fixed distance from each other in height of the tank. First sensor is performed as a hydrostatic pressure sensor and the second sensor is implemented in the form of a discrete, fixed-level sensor and installed higher than the hydrostatic pressure sensor [19]. Moreover, the system of technical diagnostics can simultaneously define not correct measuring one sensor of the given sensors. In case of incorrect measurement of both sensors their performance can be indirectly checked by their power supply.

The level of liquid in the ballast tank is measured by means of a hydrostatic method, which allows the use of devices for measuring of pressure or pressure drop.

According to the hydrostatic method at zero value of the angles of the roll and trim of the floating dock, the real value of the liquid level in the reservoir L_r determined by the formula:

$$L_r = \frac{P}{\rho_l g}, \tag{6}$$

where L_r is the value of the liquid level, measured with the help of LPS; P is the value of the hydrostatic pressure of the liquid, measured with the help of LPS; ρ_l is the density of the liquid; g is the acceleration of free fall.

Technical diagnostics of level sensors is based on PLD with FPGA architecture using VHDL models [20-23], implemented in the form of FSM charts is designed in computing environment Active-HDL (company Aldec Inc, USA). The solution proposed by the authors for technical diagnostics of sensors for determining the levels for one ballast tank is shown in Fig. 3.

The technical diagnostics according to the FSM diagram is carried out as follows**:**

– initialization of the first state of S1 in which the values of the faulty operation of the discrete level sensor (ErDLS <='0') and the value of the faulty operation of the hydrostatic pressure sensor (ErHPS <='0') are reset;
– in a state S2 measured signal LPS from a hydrostatic pressure sensor, which is preamplified and digitized and in the final form corresponds to the relative units of hydrostatic pressure, are calculated by the formula (6) in value of the liquid level LF of the tank;
– in a state S3 the difference DL is calculated between a fixed level value LF (mounting height of the level digital sensor) and the value of the level LPS, received from the previous state;
– in a state S4 the absolute value L is determined received difference DL, which corresponds to the measurement error of the level sensor of the hydrostatic pressure;
– in a state S5 conduct a test of the discrete level sensor at the time, when the absolute value of the calculated difference between the fixed value of the level LF and the value of the discrete level sensor LPS exceeds the permissible threshold P2 at which should work discrete level sensor at the rising edge of the signal (F=1) with setting values F1<='1', F5<='1' (in a state S12), and at the falling edge of the signal (F=0) with setting values F2<='1', F6<='1' (in a state S11). The values F1, F2 serve to determine the change of the signal of the discrete sensor when the fixed level LF is reached, and F5, F6 - to indicate the switching of the discrete sensor in the range of the threshold value P2, in other ranges the data values F5, F6 are reset.

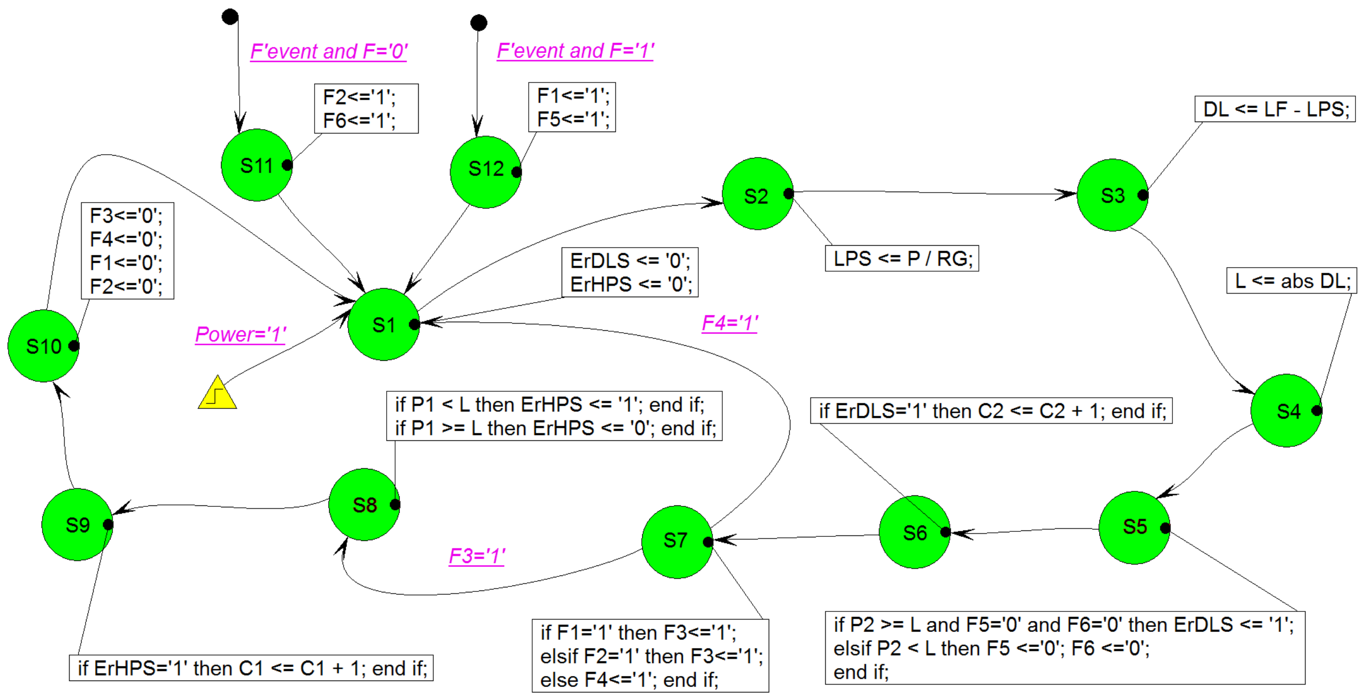

Fig. 3. VHDL model for technical diagnostics of level sensors

Accordingly, when P2 ≥ L and the discrete sensor is not switched (F5 = 0, F6 = 0), an error signal is set (ErDLS <= ‘1’), the failure of the discrete sensor is detected;

– in a state S6 carried count error counter of the hydrostatic pressure sensor and with each error (ErDLS <= '1') its value C2 is increased by one;
– in a state S7 branching is performed work FSM diagram to two scenarios. The first is triggered on condition (F4=1), which indicates the absence of the operation of the discrete sensor (F1=0, F2=0), in this case work FSM diagram will enter the cycle of states S1→ S2 → S3 → S4 → S5 → S6 → S7 → S1. The second scenario is possible if at the time of the first scenario (cycle), the discrete sensor operates in the case of the rising edge of the signal (F=1) or falling edge of the signal (F=0) and through the states S11 and S12 the corresponding values are entered F1=1 or F2=1, which in the future will activate the condition (F3=1) to go to the state S8;
– in a state S8 checking the measurement error level measurement is performed L to reach the maximum allowable value for this hydrostatic sensor. If the measurement error level L is equal to or less than the maximum permissible inaccuracy P1 (P1 >= L) then the hydrostatic sensor is in working order (ErHPS <= '0'), however, if the value of the measurement error of level L is more than the maximum value of permissible inaccuracy P1 (P1 < L), then the hydrostatic sensor is in fault condition (ErHPS <= '1');
– in a state S9, the value of the number of errors in the hydrostatic pressure sensor is falsified and with each error (ErHPS = 1) its value C1 increases by one;

the completion of the diagnosis of the hydrostatic sensor occurs at state S10 where the conditions of transitions are cleared (F1, F2, F3, F4), after which the work of the FSM of the diagram begins again from the state S1 until the Reset (Power = 1).

The computer simulation results of the proposed technical diagnostics of level sensors are presented at time diagrams (Fig. 4).

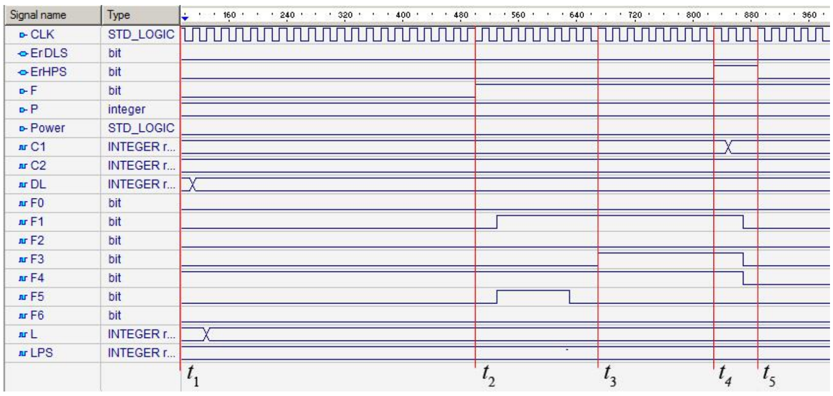

Fig. 4. Simulation of technical diagnostics of level sensors

Modeling of technical diagnostics is carried out for the case of improper operation of a hydrostatic pressure sensor. All signals of the FSM diagram are modeled digitally and linked to the clock pulse generator CLK.

At time t_1 - t_2 there is a constant operation of the sensors in the long-term filling or emptying of the ballast tank, namely the measurement of the hydrostatic pressure sensor is recorded, and the discrete level sensor remains in the unchanged state, the sensor cycle is performed at the condition of F4 = 1. At time t_2 - t_3, when the liquid level passes through the fixed value of LF, the correctness of the operation of the digital level sensor is checked by comparing its level value with the level value based on the hydrostatic sensor, if the discrete sensor has been switched at this time (in this case on rising edge of the signal F = '1'), this means that it works correctly and sets the value F1 <= '1' , F5 <= '1', then the value F5 is reset as the ballast tank is filled or desolate (P2 < L). At time t_3 - t_4, the condition F3 = 1 is set and the comparison of the registered electric signal coming from the hydrostatic pressure sensor and the correspondence to its current value of the liquid level LF in the ballast tank begins. In this case, the fault of the hydrostatic pressure sensor (ErHPS <= '1') is recorded, since P1 < L, the fault is noted in the sensor errors meter, by increasing the C1 by one. The end of the simulation of the technical diagnostics is accompanied at the time t_4 - t_5 by resetting the conditions F1 <= '0', F3 <= '0', and resetting the error rate ErHPS <= '0'.

4 Processing and Visualization of Data of Technical Diagnostics in Cloud Service

To determine the results of the technical diagnostics level sensors of the ballast system floating dock by specialized staff at the coast control post it is expedient to apply the concept of the Internet of things with modern cloud technologies [24-28].

Various cloud services are available today for processing data: Azure, Freeboard, Blumix, Thingspeak, Thingworx and others. These technologies are actively used to create technical projects. The main features that differ between them are: reliability of data, the speed of processing data streams, the ability to work in real time, etc. But to assess the different Internet of things projects in the nearby future, the standardization is actively rooted in order to form a unified and consistent regulatory normative base for the practical implementation of projects on this or that cloud service. Many international organizations, non-governmental associations, alliances of manufacturers and operators, partner projects are engaged in the issues of standardization and practical implementation of the internet of things projects.

For these tasks, the ThingSpeak service is chosen, which is an open platform for Internet of Things projects with an API for application programming. ThingSpeak allows you to create a software application for monitoring the performance of sensors in real time. An important advantage of ThingSpeak before competitors is the powerful support of MATLAB development tools for data processing and visualization of graphic images.

The organization of this approach for remote technical diagnostics of sensors begins with the transfer of PLD data processing results to a single-payment computer that has an Internet access (via a connected WiFi router with a 4G modem). The functions of a single-board computer include the systematization of all diagnostic data of the level sensors as well as the preparation and subsequent transmission of them using the HTTP protocol through the cloud-based ThingSpeak service for subsequent deregulation and visualization.

The data is sent to ThingSpeak in so-called channels, with each channel allowing you to store up to 8 fields of data, using a digital or alphanumeric character each (up to 255 alphanumeric characters each). In the channel, there are also fields for recording the location of the object of monitoring or control (Latitude, Longitude, and Elevation) and others. Each channel has its own unique two 16-value API keys, the first one used to identify the channel when writing data in its fields, and the second one for reading the data from the fields of the same channel. And at suspicion of hacking of keys of channels it is possible always to generate new keys. In general the sphere of information security is actively developing with the use of ever more powerful encryption tools, highly reliable firewalls, and a variety of VPN technologies. Requirements for cybersecurity and risk assessment methodology for industrial information control systems are adapted from the requirements for IT systems [29]. This category has published a large number of NIST guidance documents [30, 31, 32]. Among them, NIST SP 800-82 [32] describes the difference between IT systems and information control systems and provides guidance for protecting systems, including SCADA systems, distributed control systems (DCS) and other systems that perform control functions. In this case, only data sending from the level sensors to the cloud without the possibility of back transfer is implemented as well as the indicators of the sensors are processed at the local control level and indirectly can be compared with the data on the cloud service.

Work with technical diagnostics data in ThingSpeak channels is carried out using periodic POST and GET queries with the indication of the key API and the value for the corresponding channel field. Moreover channel feeds supports XML, JSON, and CSV formats for integration into applications.

Also, downloading data in channels can be implemented through URL-address. For example, if the key is API - XXXXXXXXXXXXXXXX, the URL for updating fields 1 and 2 with values 1 and 0 is the following: «http://api.thingspeak.com/update?key=ABC1234L6789STIV&field1=1&field2=0».

Each used channel of data entry is stored with a date and timestamp as well as assigned a unique entry ID (entry_id). Accordingly, the stored data can be obtained by time or by entry ID.

Thus, in the ThingSpeak service, one channel was used to send and store technical diagnostics data of two level sensors (hydrostatic and discrete). The state of operation of the hydrostatic and discrete sensors is shown on the service ThingSpeak (Fig. 4).

The Fig. 5 shows the process of technical diagnostics of level sensors in real time. The left side shows the operation of the hydrostatic pressure sensor, which, as depicted in the screen during its operation, switched to a non-operating state, the level of the red line changed ($0 \rightarrow 1$). From the right to properly demonstrate the working sensor at the full time of its ex-operation, the red line is unchanged ($0 \rightarrow 0$).

In real situations, there will be a need for much higher volumes of diagnostic data transmission of level sensors. The standard ThingSpeak license can be used to measure diagnostic issues of the floating docking system. With a standard license, you can update the data from the level sensors once a second, but in general, this version allows you to process and store 33 million messages within one year. Moreover, recording up to 8 fields in one ThingSpeak channel is defined as a message (each message can not exceed 3000 bytes).

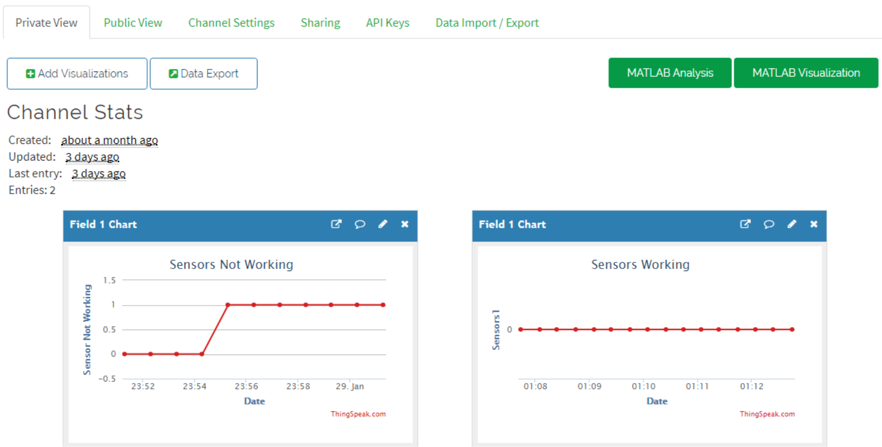

Fig. 5. Web interface of technical diagnostics of level sensors in the ThingSpeak

5 Conclusions

In this paper we propose an approach of designing the intelligent system for remote diagnostics of level sensors in the floating dock ballast complexes. Particular attention is paid to certain requirements for the safety and reliability of the system and the application of technical diagnostics of level sensors.

The process of technical diagnostics involves the presence of an object of diagnosis, diagnostics and a human-operator. The measurement, control and logic operations are performed during the diagnosis. Diagnostic data processing is performed using VHDL models in order to determine the true state of the level sensors.

The information about the current technical state of sensor gauges is displayed graphically on a computer monitor using the cloud-based Thing-Speak service. The results of the evaluation of the states of the sensors are used to make a decision about the further use of one or another sensor.

Further research should be conducted towards the development of the IoT based systems with improving of the network infrastructure through increasing of data transfer performance and connection reliability as well as eliminating of unexpected delays between local level devices and their serving cloud servers.

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Plausible Event-Tree Networks for Knowledge Representation in Real-Time GIS-Based Decision Support Systems

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Abstract. Event-based knowledge representation models providing sufficient detail in space and time are often necessary for real-time GIS-based decision support systems. The paper is devoted to developing such a model based on a plausible event tree network, which is built over a spatial model of a terrain discretized with a grid of uniform-sized cells. Each event has not only time reference, but also spatial reference, and describes a transition of the cell from one state to another. It combines different kinds of likelihood assessments (probability, fuzzy, or rough) using various plausibility models. The paper describes the event tree network-based knowledge representation, which can be used to describe a multitude of interacting processes on the terrain. An experiment based on real data describing a forest fire cascade has been conducted and has confirmed the validity and usability of the proposed model for the considered class of GIS-based decision support systems.

Keywords: Knowledge Representation Model, Event Tree Network, Likelihood, Spatial Configuration, Decision Support System

1 Introduction

Natural systems include a multitude of interacting processes, which evolve in space and time. Some of them are destructive and cause deaths, injuries, and a huge damage to property and infrastructure. Now, people face a problem of real-time decision making in conditions of natural destructive processes. However, developing the decision support systems (DSS) is a complex and non-trivial task because most of such processes arise unexpectedly, proceed fleetingly, evolve in space and time transiently, non-linearly, and have a stochastic nature. Processes of a destructive nature distributed over a confined terrain give rise to a variety of hazards, threats, and risks to various objects [1]. Often they can lead to emergencies. Thus, a GIS-based real-time DSS for the natural emergencies response is a topic of current interest.

Giving the fact that natural emergencies are poorly modeled and unpredictable, well-studied classical decision support approaches cannot be used for such kind of processes

[2]. The efficiency of response operations strongly depends on the availability of observations of destructive processes, as well as on the validity and usefulness of the observed information representation.

The most frequently observed information is represented as event streams, which represent series of time-stamped events [3]. Usually, event sequence analysis looks at the sequence of events and time gaps between events [4].

Knowledge representation about a multitude of events occurring jointly and simultaneously has been studied in many fields of knowledge. The greatest number of formal ways of presenting knowledge about events was proposed in the field of natural language processing, such as Rich Entities, Relations, and Events (Rich ERE); Light Entities, Relations, and Events (Light ERE); Event Nugget (EN); Event Argument Extraction (EAE); Richer Event Descriptions (RED); and Event-Event Relations (EER) [5]. Those representation models are focused on event processing and event-event relations aimed at inference, causal relationships, and anomaly detection across several languages [6].

Event-based structures are considered as building blocks for creating and updating situation models related to comprehension [7]. The definition of an event is "a segment of time at a given location that is conceived by an observer to have a beginning and an end" [8]. All of the above-mentioned approaches are based on semantic meaning, use strictly-defined notions of events, time and space and do not use the hierarchical structures of time and space necessary for GISs-based real-time DSSs [9].

Approaches, where representations do not take on semantic meaning, include Causal events, Force dynamics, Stochastic Context-Free Grammars, and Spatio-Temporal Derivatives [10]. Despite the fact that they differ in methods, they employ the event structure representations, which are very hard for decision-maker interpretation.

Taking into account the nature of the events, we can emphasize the existence of two basic approaches, probabilistic and non-probabilistic. Probabilistic approaches include Variance propagation, Monte Carlo sampling, variations of the dynamic Bayesian network, Hidden Markov Models, and imprecise probabilities [11]. Non-probabilistic methods include those based on fuzzy sets theory and possibility theory [12].

However, an insufficiency of statistical data for probabilistic models, a lack of well-known membership functions or degree of possibility for non-probabilistic models, as well as their common feature of a high computational complexity prevent their efficient use. Extensive reviews on this topic with respect to a considered class of DSSs have been presented in the literature [13, 14].

The event trees allow modeling of a sequence of events, forming the structures of any level of complexity [15]. The event trees can be adapted to different ways of uncertainty accounting (probabilistic, fuzzy, rough, etc.). The limitation of the event trees used in the existing works lies in the fact that the events are referenced to time points rather than to spatial locations. However, this method is very flexible, is open to using hierarchical structures and have a big potential for evolution.

The above-mentioned review enables to conclude that existing event-based knowledge representation models correspond very weakly to the systems of the considered class, and do not provide the acceptable efficiency of DSS. This paper is dedicated to developing the event-tree knowledge representation model, where events are referenced to certain time and locations and can be organized into hierarchical structures with respect to time and space. Such model should be suitable for solving the problems of decision-making on natural emergencies response in real-time GIS-based DSS providing required efficiency.

2 Spatial Model

Assume that the destructive processes spread over a certain area of interest (AOI).

Consider a three-dimensional Euclidean space C, which contains the AOI as an openly connected subspace $X \subseteq C$. Suppose that each point $x \in X$ has a non-empty finite set of attributes $A = \{a_1,...a_m\}$, V_{a_i} is a domain of $a_i \in A$, $V = \cup_{a_i \in A} V_{a_i}$, and f is an attribute value function such that $f : X \times A \to V$ for each $x \in X$.

A spatial model is discretized at three levels: the lower level contains cells of equal size, the middle level consists of spatial regions of different sizes, and the upper level represents large spatial areas.

At the lower level, we impose a metrical grid of coordinate lines with size δ on C using a linear map ϕ such that coordinate lines form a set D of the cubic cells with the size being $\delta \times \delta \times \delta$, $\phi : D \to C$. Thus, space C is discretized by a grid $D = \{d_{xyz}\}$ of isometric cubic cells d_{xyz}. A cell $d \in D$ is a spatial object of a minimal size. Each cell $d \in D$ is associated with a set of attribute values, which is called the cell state, via the value function $f(d, A)$. The proposed discretization assigns the equal values of the attributes to each point belonging to a certain cell d, therefore each cell $d \in D$ represents a homogeneous area of the AOI in the sense of the attribute values A. Thus, each cell $d \in D$ can be reduced to a point of X, and all points of this cell are A-indiscernible: $(\forall d_1, d_2 \in D)(\forall a \in A)\left[f(d_1, a) = f(d_2, a) \right]$.

At the middle level, the subspace X can also be divided into a finite set of disjoint objects having geometric shapes, which represent the certain homogeneous areas of the AOI. Consider a non-empty subset of attributes $A_i \subseteq A$. Define an A_i-indiscernibility relation [10] $R_D^A = \left\{ (d_m, d_n) \in D \times D \middle| \forall a_j \in A_i, f(d_m, a_j) = f(d_n, a_j) \right\}$ on the set of cells D. If $(d_m, d_n) \in R_D^A$, it means that all pairs of different points y, z that belong to the different cells d_m, d_n have the same values of attributes $a_j,...a_m \in A_i$ as all pairs of different points x, y of each cell d_m, d_n. Thus, we define a middle-level structural element of the spatial model as the homogeneous spatial area that is uniform in the sense of attribute's values and can be represented by the approximating set of cells. Such element is called a region and denoted by h. All the cells belonging to the region h are A_i-indiscernible. Each region can represent the object of a certain class on a GIS map that is named as geotaxon. The geotaxons cannot overlap or cover one another, but they can be adjacent or adjoin to one another. Thus, a continuity and a connectivity are their important features (spatial concentration of the underlying cells).

However, we often need to analyze the spatial areas containing a plurality of objects with the certain relations between them. Such spatial areas may consist of a plurality of separate regions spatially distributed over X , and represent zones homogenous in the sense of definite assessments of some indicators (e.g. danger, threat, and risk), which depend on the values of attributes $A_j \subseteq A$. Obviously, they do not have the property of the continuity. Consider a set of regions $H = \{h_1,...h_k\}$. Define the A_j-indiscernibility relation $R_H^{A_j} = \left\{\forall h_l, h_q \in H,\ \forall d_m, d_n \in D,\ \exists d_m \in h_l, d_n \in h_q \middle| \forall a_k \in A_j,\ f\left(d_m, a_k\right) = f\left(d_n, a_k\right)\right\}$ on the set of regions H [16]. Obviously, all regions belonging to $R_H^{A_j}$ are A_i-indiscernible in the sense of the same values of attributes $a_l,...a_p \in A_j$. Thus, we define distributed spatial area H as an upper-level structural element of the spatial model that is uniform in the sense of attribute's values and is represented by the approximating set of regions.

3 Events and States

Suppose the set of attributes A can be divided into subsets: not changing over time (static) attributes A_S, time-varying (dynamic) attributes A_D, slowly changing (environmental) attributes A_E, $A = A_S \cup A_D \cup A_E$. We next define the cell state categories.

Suppose $W = \{w_0,...w_i,...w_F\}$ is an ordered set of the cell state categories (modes), where w_0 is the initial mode, w_F is the final mode, and w_i is the transitional mode. Suppose ϑ is a category function such that $\vartheta: D \times A \to W$. Each category $w \in W$ has three subcategories: the cell status $w_S = \vartheta(A_S)$, the cell condition $w_C = \vartheta(A_S \cup A_E)$, and the cell stage $w_D = \vartheta(A_D)$. Each state category (and subcategory) is a certain subspace of the n-dimensional attribute values space $V_{a_1} \times ... \times V_{a_i} \times ... \times V_{a_n}$.

Each random change of values of any subset of dynamic parameters $A_k \subseteq A_D$ can change the cell condition w_C in such a way that the cell stage w_D must also change. This change is not necessary, but possible. If the cell condition w_C changes, the cell possibly goes into another state category w_i (mode of behavior).

We define an accessibility relation $R_{ACC} \subseteq W_D \times W_D$ (reflexive, asymmetric, and non-transitive) on a set of stages W_D and a compatibility relation $R_{COM} \subseteq W_C \times W_D$ (non-reflexive, symmetric, and non-transitive), taken the cell condition $w_C \in W_C$ onto the cell stage $w_D \in W_D$. The accessibility can be determined by a function $f_{acc}: W_D \times W_D \to \{\xi\}$, which returns the possibility of the transition from one stage to another, whereas the compatibility can be determined by a function $f_{com}: W_C \times W_D \to \{true, false\}$ taking into account that some stages may be incompatible with the certain conditions (e.g., sandy areas, which are not covered with vegetation, usually cannot be exposed to burning).

We consider each significant (perhaps, jump-like [17]) change of the cell attribute's value, which forces the cell to change its state, as an event, and denote it by y , so that $y: w_i \to w_j$. It is clear that the model of the destructive process can be represented as a model of dynamic change of states of a subset of cells covered by the process within the spatial model. Assume, during the destructive process, the cell moves through a sequence of qualitatively different classes (categories) of states. The states should be evaluated during continuous observations (monitoring) that allow obtaining time-ordered sequences of events (random event flow without consequences).

We formalize the event, the events model, and the event stream, taking [18] as a basis and introducing parameters of time and space into the model.

4 Event Model

Consider a time point set T with the initial moment $t_0 \in T$ and an order relation $<_T$, which sets a fully ordered timescale $\langle t_0, T, <_T \rangle$ over T.

In order to consider various aspects of a recorded event depending on the accuracy of its observation, it is possible to classify the events using taxonomy hierarchy. This hierarchy is denoted by I_1 and corresponds to a set of classes $Class = \{c_i\}_{i=1}^{n}$, where c_i is an event class. A partial order relation $\prec_1$ over I_1 arranges observed information in order from abstract to detailed, e.g. $c_1 \prec_1 c_2$ means that the event class c_1 contains less information than c_2.

Notice, that any event can be a part of one or more complex event structures, such as coupled, concatenated, or triggered events and their chains. Thus, it is advisable to build a composition hierarchy I_2 that corresponds to a certain composition of events such as $y_j = y_k$ в y_l, where в is disjoint union. The partial order relation $\prec_2$ over I_2 arranges the inclusion of the observed events in the complex chains, where $y_k \prec_2 y_j$, means that y_j is a composition with y_k being its constituent.

Besides that, we can build a spatial hierarchy I_3 within the spatial model with a set of elements like {*cells*, *regions*, *areas*} and the partial order relation $\prec_3$ over it, as well as a time hierarchy I_4 with the set of elements like {*seconds*, *minutes*, *hours*, *days*...} and a full-order relation $<_T$ over it. The spatial and temporal hierarchies are the basis for building the adequate space-and-time-referenced event model.

Thus, the basic element for developing the event model is the hierarchy.

Suppose each hierarchy $\Im_i$ is a triple: $\Im_i = \langle \perp_i, I_i, \prec_i \rangle$, where I_i is a set of some elements, each of which corresponds to a certain relation υ_i among them (e.g. taxonomic υ_1, inclusion υ_2, spatial υ_3, temporal υ_4, accessibility υ_5, compatibility υ_6, and so on), $\prec_i$ is the order relation over I_i, and $\perp_i$ is the least element of $\prec_i$.

Define an event signature $\mathcal{Z}$ as a tuple $\mathcal{Z} = \left\langle A, \{\Im_i\}_{i=1}^{m} \right\rangle$, where A is a set of parameters, and $\{\Im_i\}_{i=1}^{m}$ is a set of hierarchies $\Im_i$ induced by the corresponding relations υ_i.

Consider the event model $E = \langle \upsilon, \rho, \mathcal{Z} \rangle$, where υ is a variable set, ρ is a set of restrictions, and $\mathcal{Z}$ is the signature.

Define the event y in the model E as a structure $y = \langle Y, c, t, d, A_y \rangle$, where $Y \in E.\upsilon$ is a unique label, $c \in E.\mathcal{Z}.I_1$ is an event class, $t \in T$ is a time point (observation moment, $t \in E.\mathcal{Z}.I_4$), $d \in D$ is a spatial point (observation georeference, $d \in E.\mathcal{Z}.I_3$), and A_y is a set of event parameters, $A_y \in A$. Thus, the event y is a complex object that belongs to a certain class of events $c \in Class$ and gets the values of parameters of the corresponding cell $d \in D$, which contains the georeference point. Since the conditions and the accuracy of observation differ at various time points, each event y can be described by the parameters that also differ in values and accuracy.

An event sequence S in the model E is an aggregate of events ordered by $<_T$, $S = [y_1, y_2, \ldots y_n]$, such that it holds $y_1.t \leq_T y_2.t \leq_T \ldots \leq_T y_n.t$ for all events. One should refer to the event y of the sequence S_i with the index j as y^i_j, $y_i.t = t_j \in T$.

To formalize any kinds of relations established between the events and the variables in the event model E, we introduce the notion of an event path. The event path $\rho(d_i, d_j)$ is a sequence of events spreading along a chain from the cell d_i to the cell d_j. Two or more paths can be combined using a concatenation operator.

5 Assessment of Event Likelihood

Suppose L is a non-empty carrier set with multiplicative $\otimes$ and additive $\oplus$ operators. If they satisfy the conditions of idempotency, commutativity, associativity, and distributivity for any $x, y, z \in L$, we obtain a distributive quasi-lattice $R = \langle L, \otimes, \oplus \rangle$. Setting two zero-ary operations 0 and 1, as well as their absorption conditions, we obtain a bounded distributive lattice (semiring) $Z = \langle L, \otimes, \oplus, 0, 1 \rangle$ that is not closed with respect to the union [19]. Therefore, $\langle L, \otimes, 1 \rangle$ is a monoid, $\langle L, \oplus, 0 \rangle$ is a commutative monoid.

Taking into account the idempotency of the additive operator $\oplus$ with respect to L and the properties of the semiring Z, we can define an order relation $\prec_Z$ such that $\forall x, y, z \in L \quad x \prec_Z y \leftrightarrow x \oplus z = y$. Thus, $\prec_Z$ is the partial order on L that makes it possible to compare the various elements of the carrier set, so that $x \prec_{\mathrm{P}} y$ means that the value y is preferable than x.

The proposed semiring model and the partial order relation can serve us as the framework. Choosing the corresponding initial carrier set L, defining the additive $\oplus$ and multiplicative $\otimes$ operators over Z, and equipping the lattice with operations of taking the exact lower edge *inf* and upper edge *sup*, we can build a likelihood model ℓ, which can express the degree of likelihood as a measure of belonging to the carrier set.

Thus, we use a relative likelihood assessment on the scale [0,1] instead of probability to evaluate events as more possible, less possible, equally possible based on the numerical value (degree) of their likelihood. It makes possible to combine estimates of probabilities based on statistical observations, with assessments of the possibilities formed by experts, within the single framework, taking into account the possible incompleteness and inaccuracy of information represented by fuzzy or rough sets.

6 Plausible Event Tree Networks

Let us build an event tree network over the model E, based on the joint mapping of a set of induced hierarchies into the event tree structure [20].

Consider oriented connected multigraph $g = \langle v,e \rangle$, which doesn't contain cycles, where v is a set of vertices, and e is a set of arcs. Subdivide a nonempty set of vertices v into three disjoint sets: a set of leaf nodes $r \subset v$, a set of roots, which contains vertices of higher level $u \subset v$, and a set of nodes b, which are neither roots nor leaves, such that $g = u \cup b \cup r$, $u \cap b = u \cap r = b \cap r = \varnothing$. Subdivide a nonempty set of arcs e into subsets $e = e_{\prec \upsilon 1} \cup ... \cup e_{\prec \upsilon n}$, each of which reflects a certain relation υ_i over v.

We can use the likelihood model ℓ for labeling arcs with the coefficients of likelihood, which belong to the carrier set L. The presence of a transition (arc $e_{\prec \upsilon i} \in e$) between two nodes is a reflection of some relationship υ_i between the events represented by the nodes. Based on ℓ, the measures $\lambda_i \in L$ can be assigned to the arcs, expressing the degree of the existence of a relationship between two nodes connected by this arc.

The model ℓ (Fig.1) can be based on the deterministic formalism (*D*), or the probabilistic theory (*P*) for evaluation of probabilities of transitions between nodes, or the fuzzy set theory (*F*) for evaluation of possibilities of transitions between nodes, or the rough set theory (*R*) for evaluation of necessities/possibilities of the transition between nodes, of the temporal theory (*T*) for evaluation of transition times between nodes.

Likelihood model, ℓ	L	$\otimes$	$\oplus$	**0**	**1**
deterministic, D	$\{0,1\}$	$\wedge$	$\vee$	0	1
probabilistic, P	$[0,1]$	$\cdot$	$1-\prod_{i=1}^{k}(1-p_i)$	0	1
fuzzy, F	$[0,1]$	$\min_{i=1}^{k}(\mu_i)$	$\max_{i=1}^{k}(\mu_i)$	0	1
rough, R	$[0,1]\times[0,1]$	$\left(\bigcap_{i=1}^{k}\underline{d}_i, \bigcap_{i=1}^{k}\overline{d}_i\right)$	$\left(\bigcup_{i=1}^{k}\underline{d}_i, \bigcup_{i=1}^{k}\overline{d}_i\right)$	$\langle 0,0\rangle$	$\langle U,U\rangle$
time, T	$[0,\infty[$	$+$	$\min_{i=1}^{k}(t_i)$	0	∞
combined, PT	$[0,1]\times[0,\infty[$	$\left(\prod_{i=1}^{k}p_i, \sum_{i=1}^{k}t_i\right)$	$\left(1-\prod_{i=1}^{k}(1-p_i), \min_{i=1}^{k}(t_i)\right)$	$(0,0)$	$(1,\infty)$
combined, FT	$[0,1]\times[0,\infty[$	$\left(\min_{i=1}^{k}(\mu_i), \sum_{i=1}^{k}t_i\right)$	$\left(\max_{i=1}^{k}(\mu_i), \min_{i=1}^{k}(t_i)\right)$	$(0,0)$	$(1,\infty)$
combined, RT	$[0,1]\times[0,1]\times[0,\infty[$	$\left(\left(\bigcap_{i=1}^{k}\underline{d}_i, \bigcap_{i=1}^{k}\overline{d}_i\right), \sum_{i=1}^{k}t_i\right)$	$\left(\left(\bigcup_{i=1}^{k}\underline{d}_i, \bigcup_{i=1}^{k}\overline{d}_i\right), \min_{i=1}^{k}(t_i)\right)$	$(\langle 0,0\rangle,0)$	$(\langle U,U\rangle,\infty)$

Fig. 1. The likelihood models

A composite likelihood model ℓ^* is a model built on the base of models ℓ_i and ℓ_j so that the semi-ring Z^* of the compositional model is the Cartesian product of semi-rings $Z^* = Z_i \times Z_j$. A complex likelihood model μ is a shared set $\{\ell_i\}_{i=1}^{n}$ of simple and composite models ℓ_i.

Let us introduce a multigraph g over the model E.

The plausible event tree network (PETN) in the model E over the event stream $S = [y_1,...y_n]$ such that $y_i \in E.\mathcal{Y}$ is a structure $G = \left\langle g, \varphi, \gamma, \{\prec_i, \phi_i\}_{i=1}^{k}, \tau, \delta, \mu \right\rangle$, where g is an acyclic connected multigraph, $\varphi : r \to S$ is a mapping of each leaf node r into a certain event from the sequence S, $\tau : r \to T$ is a mapping of each leaf node r into a set of time values $E.\mathcal{Y}.I_4$, $\delta : r \to X$ is a mapping of each leaf node r into a spatial location $E.\mathcal{Y}.I_3$, $\varsigma : r \to \rho$ is a mapping of each leaf node r into a certain restriction from a set of restrictions ρ, $\gamma : v \to 2^{E.\mathcal{Y}.A}$ is a mapping of each node v into a set of parameters from $E.\mathcal{Y}.A$, and $\{\prec_i\}_{i=1}^{k}$ is a set of partial order relations $\prec_i$ over a set of nodes v, each of which is induced by a relation υ_i and represented by a subset of arcs $e_{\prec\upsilon i} \in e$, μ is the complex likelihood model, $\phi_i : e_j \xrightarrow{\lambda_j} \ell$ is a mapping that labels each arc $e_j \in e_{\prec\upsilon 1}$ with a likelihood estimate λ_j within the model $\ell \in \mu$.

The root nodes $h \in u$ of PETN G determine a set of sequences consisting of all events in the leaf nodes $\mathrm{r} \in r$ ordered by $\{\prec_i\}$. Each leaf node $\mathrm{r} \in r$ corresponds to certain parameters γ, a time point τ, and a spatial location δ. Each non-leaf node represents a significant event sequence, where each event is represented by the leaf node $\mathrm{r} \in r$. Thus, each PETN node corresponds to the event sequence represented by h, and its descendants represent a certain chain of the parent sequence.

PETN can be used to formalize partially ordered sets of events that occur simultaneously and jointly. In this case, the leaf nodes represent the elementary (observed) events, and the non-leaf nodes correspond to the aggregate events (sequences of elementary events). An important feature of the formalized PETN is its ability to expanding the set of representable relations between events by any new relations υ_k adding a corresponding subset of arcs e_k to e and implementing a corresponding order relation $\prec_k$. A complex composition structure can be created in the presence of several event sequences within the model E and some different relations between them. Fortunately, the composition hierarchy I_2 allows us to consider PETN as a composite structure, which includes the other tree structures as elements.

A composite event tree network within the model E with respect to the event sequence set $\{S_j\}_{j=1}^{n}$, $S_j = [y_1^j,...y_m^j]$ such that $y_i^j \in E.\mathcal{Y}$ is a structure like $G^{e} = G_1$ в ... в G_n. The structure G^{e} can be represented as a forest of poly-multi-trees. A fragment of the fuzzy-temporal (*FT*-)PETN is shown in Fig. 2.

We can notice that an aggregate event y_{111} is a sequence with an event y_{1111} and possibly (with a degree 0.8) the event y_{1112} following with an interval of 1 to 5 minutes. Also, if the event y_{111} is a part of an abstract event y_{11}, it is possible (with the degree 0.5) that event y_{112} should occur within an interval of 2 to 6 minutes.

The proposed formalization of the PETN can be considered as an abstraction of the known model of the Belief Network [14].

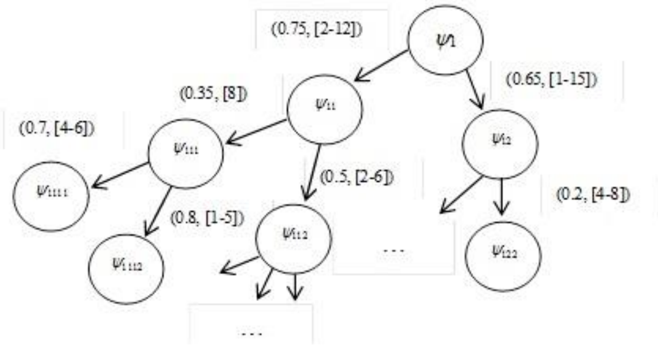

Fig. 2. A fragment of fuzzy-temporal (*FT*) PTEN

7 PETN Implementation

The proposed plausible event-tree networks were implemented as PETN dynamic library written in Python, which provides a high-level programming interface to the developer.

The PETN library includes a set of classes and methods that allow creating complex structures of events on the fly and maintaining them. The structure of the PETN Library is illustrated in Fig. 3.

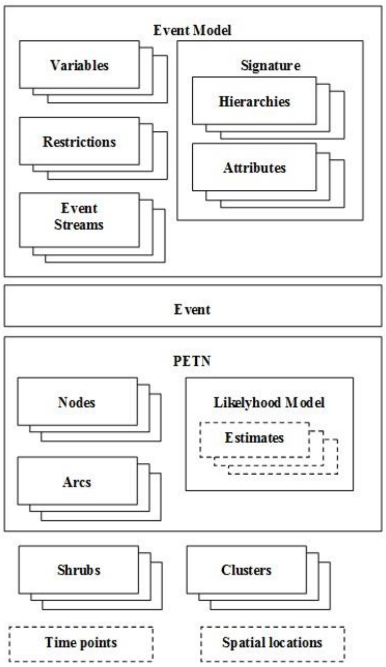

Fig. 3. Structure of PETN dynamic library

The main class of the library is the **Event** class. The sequences of events are collected in ordered lists that representing event streams. Thus, objects of the **event** class are building blocks for the objects of the **Event streams** class.

Event model class allows describing a multitude of event streams, variables, and constraints, as well as defining necessary hierarchies for events and setting their attributes. Thus, a certain event model environment can be constructed.

Hierarchies can be described as the ordered lists of elements, where the first element is always the least element.

PETN class describes interconnected sets of nodes and arcs, where each node object is associated with a certain event object from **Event model**, as well as each arc object gets its estimate from the corresponding likelihood model.

The main feature of the PETN object is that each event and, consequently, each node of PETN has reference to the corresponding time point and geolocation.

All classes of PETN library have a unified CRUD interface that implements the corresponding set of methods (create, read, update, and delete). In addition, all ordered lists of objects have an additional interface, which takes into account their indexing.

Classes **Shrubs** and **Clusters** are very important because they allow cutting and separately handling a certain part of the tree-like structure. The **Shrubs** class allows getting some node of PETN as root, and then pull out the entire set of nodes and arcs connecting them from the PETN structure. The resulting subtree growing from the root node can be further considered as an independent PETN structure with all the possibilities for its processing and analysis. On the contrary, the **Clusters** class allows to simultaneously specifying a non-empty set of root nodes, so the whole bundles of bushes growing from these roots can be processed and analyzed.

Objects of **Event** and **Event stream** classes can be serialized and deserialized using a data source associated with a certain PostgreSQL database. Objects of PETN class can also be serialized and deserialized but its data source is associated with another PostgreSQL database. Thus, event streams are accumulated and stored in one database, while the corresponding event-tree networks are grown and stored in another, separate database. This makes it much easier to monitoring events.

The goal of PETN Library is to make the development of PETN structures using Python as quick, flexible, and elegant as possible using its programmable interface.

However, for use in the DSS, it is necessary to implement an interface that allows the operator to perform certain operations with PETN structures without directly programming. Therefore, a PETN description and manipulation language (PETN-DML) interpreter were developed and used to translate requests of DSS into series of method calls for PETN objects through the PETN library.

8 PETN Model Implementation in the DSS

The proposed knowledge representation model based on the plausible event tree network was implemented using the PTEN Dynamic libraries.

To make the development of GIS-based DSS quick and flexible, it uses Python programming language as well as the following tools (Fig. 4):

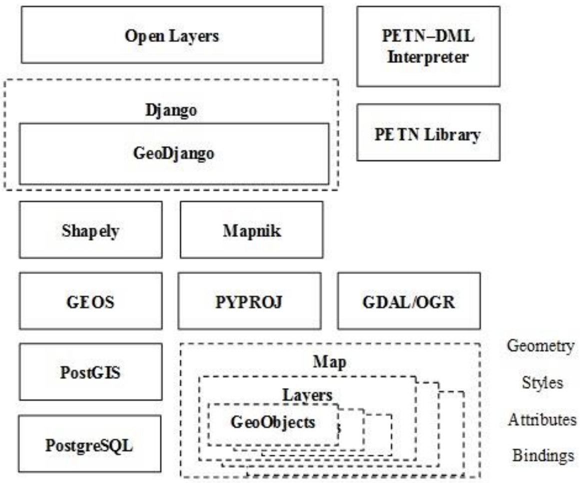

Fig. 4. Structure of the DSS implementation

- DBMS PostgreSQL;
- Geospatial extension PostGIS for PostgreSQL;
- PostgreSQL adapter psycopg2 for Python;
- Framework Django;
- GIS extension GeoDjango;
- GDAL/OGR geospatial libraries;
- GEOS Geometry Engine library;
- Mapnik – open source toolkit for rendering maps;
- pyproj – library for cartographic transformations and geodetic computations;
- Shapely – planar geometry library;
- PETN dynamic library;
- PETN interpreter;
- OpenLayers mapping library.

The web-oriented GIS-based DSS use the WGS84 datum and GeoJSON as an open format for encoding geographic data structures, as well as GML (geographic markup language) as an open XML-based standard for the exchange of GIS data.

The OGR library is used to read and write geodata in vector format, which was obtained from the Natural Earth website.

The Mapnik library takes the geodata from the PostGIS database and turns it into clearly visualized images. It provides a Map object, representing the map as a whole, Layer objects representing thematic layers with the content of the map, and Style objects that tell how to draw various layers.

Shapely is based on the dynamic library GEOS (the engine used in PostGIS) and manage spatial rather than geospatial data. It assumes that the geodata is already projected to a two-dimensional coordinate plane before they can be manipulated, and the results can be converted to geographic coordinates if desired.

The geospatial extension PostGIS is used for storing spatial data and working with them in the object-relational database PostgreSQL.

Using PostGIS and Mapnik, we ensure that the geospatial data is split into a large number of regular cells organized into rows and columns that are elements of a regular cubic grid in a certain data model. Thus, each cell is geographically referenced, that is, it has its own coordinates within the Map object.

Applying PostGIS from the Python programs, we have to use PostgreSQL DBMS as well as the psycopg2 PostgreSQL database adapter for Python.

9 The Results of the Research

The developed GIS-based real-time DSS is based on the PETN model implementation and allows evaluating a number of indicators, e.g. danger degrees, threats, and risks, for a given set of target objects, as well as providing the geospatial analysis of emergencies in real time disaster situations.

Fig. 5 depicts the map of Tsurupinsk forestry (Kherson region, Ukraine), which has been implemented using the proposed spatial model grid with the variable cell size.

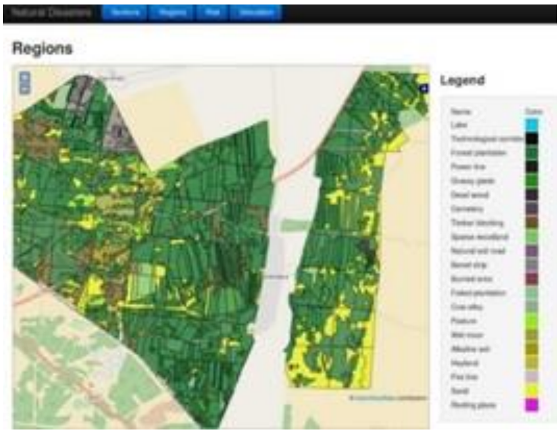

Fig. 5. Representation of the Tsurupinsk forestry in GIS-based DSS Forest Project

To examine a validity and an efficiency of the proposed PETN model, we have conducted an experiment based on the information on series of large-scale forest fires, which had been taken place in Tsyurupinsk and Golopristan forestries (Kherson region, Ukraine) on July 20-31, 2007.

We have modeled the ongoing processes via PETN and evaluated the total time of decision-making as well as the losses at the end of the processes. We have also varied the number of ignitions investigating its impact on the DSS assessment time, which enabled the evaluation of the influence of these parameters upon a risk assessment performance. The number of ignitions has been varied from 1 to 8, and the corresponding number of nodes in obtained PETN has been respectively varied from 1,438 to 18,582.

Although the performed experiment would benefit from comparing our results with results based on some alternative implementation, we did not have an adequate software library for comparison. Therefore, we have compared the results obtained with the implemented DSS, with the results obtained with manual decision-making.

The results of the experiment are depicted in Fig. 6.

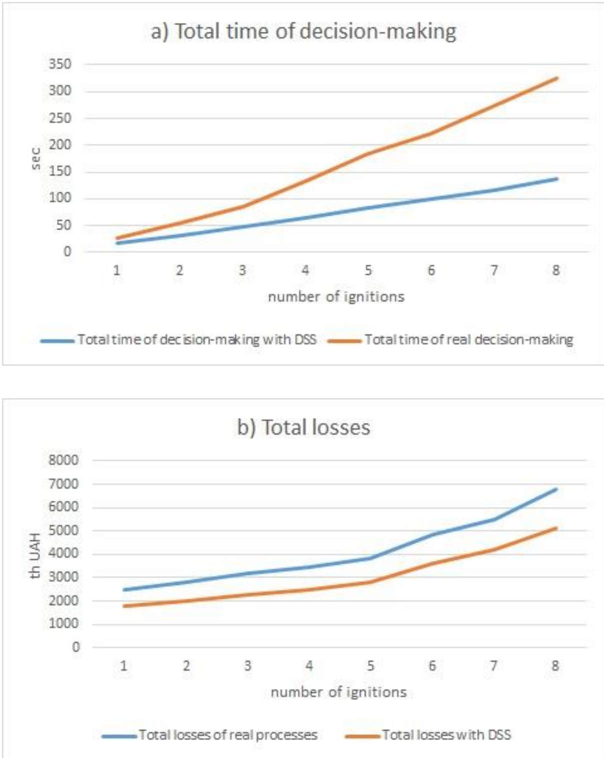

Fig. 6. Total time of decision making (a) and total losses (b) vs. number of ignitions

As our results indicate, the PETN model provides an opportunity to represent the dynamics of destructive processes adequately. The use of the proposed model makes it possible to accelerate the decision-making process under destructive process conditions by about 60% (for 5 ignitions) and above. The graph Fig. 6(a) shows the tendency to a significant increase of DSS efficiency with an increase of the number of ignitions (from 6 and above) as a consequence of the limitation of human heuristic capabilities (without DSS). The achieved acceleration of the decision-making process leads to decreasing the total losses by 35% and above in the same conditions.

A general view of the DSS performance curve in Fig. 6 shows that the dependence of the decision-making time on the ignition points number is linear. Since the dependence of the number of PETN nodes on the number of ignition points is also linear, it is confirmed that PTEN inference time depends linearly on the time with respect to the number of nodes.

10 Conclusions

The knowledge representation model based on the plausible event tree networks is built as a result of conducted research. The model represents a sequence of cell state transitions considered as events within the spatial model. Unlike the other known approaches, PETN allows referencing events to both the time and spatial points over the digital terrain model. Thus, we can closely integrate the proposed PETN model into GIS-based DSS, and, as a result, provide an adequate mapping of the dynamics of the spatially-distributed processes. Another important advantage of the proposed PETN model is its satisfactory performance, which ensures DSS operability in real time.

The proposed knowledge representation method based on plausible event tree networks also gives the opportunity to describe events based on incomplete and unreliable observed parameters as the likelihood assessments of transitions of the cell from one state to another. Unlike to well-known probabilistic or possibilistic approaches, PETN formalism can combine time measures and various likelihood measures (probability, possibility, fuzzy, or rough) in one frame depending on the specific conditions of the uncertainty of observations.

The proposed PETN model is applicable in all domains, which can be considered as a multitude of interacting spatially-distributed processes evolving in space and time. Such processes often give rise to a danger and risk due to dynamic locations and dynamic spatial relationships of interacting objects. In most cases, this causes their destructions and can lead to critical situations or emergencies. Solving such problems requires real-time GIS-based DSS containing a digital model of confined space (terrain). Thus, the proposed PETN model can be the basis of real-time GIS-based DSSs.

The proposed PETN model has been used in GIS-based DSS for a natural emergency response. Currently, intensive research is also being conducted on the use of the PETN model for solving problems of safety assessment in vehicle-onboard control systems and threat assessment in computer security systems. Research results show that the proposed approach significantly reduces the computational complexity of problem-solving in the above-mentioned domains.

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Ukrainian Banks' Business Models under Systemic Risk

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Abstract. In this article we analyze specific origin of business models in Ukrainian banking system over the period of 2014-2017. Using K-mean clustering techniques five basic business models were identified due to the combination of bank asset items and liabilities sources, retail and corporate focus, equity to assets ratio which appears to be abnormally high for frozen banks. We produced migration matrix for business models from the start of systemic crisis in 2014 till recovery in 2017. We analyzed how defined strategies have affected risk and efficiency of Ukrainian banking system under systemic instability.
The results of the study contribute to a deeper understanding of riskiness of business models through different periods of financial cycle. Retail and particularly "non-scheme" corporate bank business models were the most sustainable compared with "retail funding to corporate lending" type of banks. Our results enable to develop more efficient macroprudential tools grounded on heterogeneity of bank business strategies.

Keywords: banks' business models, universal banks, frozen banks, systemic risk, financial crisis, banking system of Ukraine.

1 Introduction

The crisis of Ukrainian banking system during 2014-2017, have highlighted strong business models impact on banks' financial sustainability. For instance, among the defaulted banks local private banks that were associated with industrial business groups held leading position. Such banks performed related party lending risky policies at the expense of individuals. Other group of liquidated banks was presented by banks with non-transparent ownership structure, some of them also was involved in money laundering. Since the configuration of the banking system by key parameters such as ownership structure, size, business strategy main features affects its risk profile, there is a need for identification and in-depth research of banks' business models frameworks of the Ukrainian banking system.

The main findings of presented research were confirmed by the use of quantitative methods. Using unsupervised learning techniques of cluster analysis, five key business models were identified and described: universal, retail, corporate, "retail finance to corporate lending" (RF-CL) and frozen. The inter-clusters migration, the level of financial sustainability of each business model and its adaptability to the systemic risk implementation during the 2014-2017, were investigated.

The cluster approach, despite its mechanistic nature, proved to be a useful tool for grouping of existing banks by key business model types. Its results not only confirmed a number of our existing hypotheses regarding the peculiarities of the development process and effectiveness of banking strategies under uncertainty, but also enriched with new insights that complemented the ongoing discussions on financial stability in the professional, business and political circles. For example, the empirical results confirmed such hypotheses as: 1) the insider banking business model, which is inherent in the local private banks, failed to pass the systemic crisis; 2) the majority of the failed banks due to the cleansing policy was in RL-CL and frozen clusters; 3) the strategy of focusing on the retail or classical corporate direction proved to be less popular in Ukraine, however, the most effective and sustainable during the realization of systemic shocks; 4) the universal banking business model, in spite of long-standing problems with toxic loan portfolio and low efficiency (especially in the sub-segment of public banks), shows the first signals to the recovery and continue to define the structure of the banking system.

The rest of the paper is organized as follows. Section 2 reviews recent research papers on banks business models and the systemic risk. Section 3 describes the methodology of the presented research to identify business model clusters and presents the data sample. Section 4 discusses our main findings related to identification, financial performance and risk evolution of banks in each business model. Section 5 concludes.

2 Literature Review

The process of identification and characterizing of banks' business models is widely disclosed in numerous publications of foreign researches, such as: Ayadi et al. (2016), Japparova & Rupeika-Apoga (2017), Soares (2017), Farnè & Vouldis (2017), Lautenschläger (2017), Hryckiewicz & Kozlowski (2014), Demirgüç-Kunt & Huizinga (2010), Roengpitya et al. (2014), Mergaerts et al. (2016), Köhler (2015), Van Oordt et al. (2014), Grossmann & Scholz (2017), Tomkus (2014), Ferstl & Seres (2012), Altunbas et al. (2011).

Among Ukrainian scholars and practitioners, the theme of banks business models has become much less widespread, with the exception of Panasenko & Bortnikov (2016), Zarutskaya (2012), Ivasiv et al. (2014), Lyubich et al. (2016), Rashkovan & Pokidin (2016).

Our work is considered as the continuation of the above-mentioned studies on this topic. One of the goals of our paper is to confirm the findings of previous studies using the different methods of quantitative analysis for identifying business models. At the same time, our article covers a wider time interval of financial instability, which allows to form a better and more consistent view of banking system evolution under systemic risk.

The main aim of this paper is to identify and analyse the core economic characteristics, financial performance and risk profile evolution of the different business models of Ukrainian banks under systemic risk pressure.

3 Methodology

3.1 Data

The study was based on the financial data published by the National Bank of Ukraine (NBU) on quarterly basis. For the study, panel data of the general population of banks were used as of 01.01.2014 (pre-crisis dataset) and 01.10.2017 (post-crisis dataset). Pre-crisis dataset contains financial indicators of 180 banks while post-crisis one includes 86 banks. In both cases this is a total number of banks operated on the Ukrainian market. These datasets allowed to detect banking business models structure changes due to the systemic crisis.

3.2 Research Methods

The identification of business models took place with the help of k-means clustering method, which is often described by our predecessors as “state-of-the-art” analytic tool. Cluster analysis is an appropriate statistical technique for grouping a set of our bank/year observations into distinct clusters (which represent different business models) to confirm a certain degree of similarity within each cluster. The basis of this assignment is a set of indicators chosen by researchers to measure the distance of each variable's value from others [Ayadi et al. (2014)]. The data collection exercise spanned over thirty indicators in the pre- and post-crisis datasets. The distinctness of each clustering solution was checked by relying on plot of the total within-groups sums of squares (WSS) against the number of clusters in each K-means solution. Here the Elbow method was used, which is based on the total WSS as a function of the number of clusters: we choose a number of clusters so that adding another cluster doesn’t improve much better the total WSS [Kassambara, (2017)].

3.3 Variables

The indicator selection procedure generated the following set of variables as the most definite and easiest to interpret, which was used in the clustering:

1. **Retail loans to total loans** (%). Identifies the share of retail loans in the total loans, which is expected to be greater for retail-oriented banks that are more active lenders to general public. For corporate-oriented banks the indicator moves close to zero.

2. **Retail deposits to liabilities** (%).The instrument shows the share of retail deposits in total liabilities, which is great for banks that concentrate their funding activity in the retail deposit markets. Much like retail loans to total loans indicator, small value of this variable is a useful parameter to indicate corporate-oriented business model.

3. **Non-deposit resources to liabilities** (%). Calculated by dividing the sum of other banks funds and issued debt to total liabilities, the variable is negatively correlated with customer deposit funding. Wholesale funding exposures are typical for banks with corporate or investment business models and could imply risks emanating from interconnectedness.

4. **Equity to assets ratio** (%). On the one hand lower value of this instrument indicates higher bank's financial leverage, on the other hand abnormally large capital adequacy ratio represents the balance sheets of inactive frozen or “zombie” banks, which have not access to the deposit and funding markets.

5. **Net assets** (logarithm). The instrument is a good bank size proxy to divide financial institutions into small and large ones which have different possibilities in economy of scale and choice of business strategy.

That final set of indicators used in identifying the business models is given in Appendices in Table 1. Then variables on bank activities, financial position, financial performance, risk factors, as well as regulatory indicators were constructed from pre-crisis and post-crisis subsets. Descriptive statistics of the variables used in further assessing of chosen clusters is given in Table 2.

4 Empirical Findings

4.1 Clusters Identification

As a result of the cluster analysis, there were identified 5 groups of banks that had common business models of input indicators, namely: universal, retail, corporate, "retail finance to corporate lending" (RF-CL) and frozen (see Fig. 1).

The **universal** business model is characterized by a combination of retail and corporate business directions both from the point of view of attraction of funds and credit activity. As the analysis showed, it is the largest group in terms of assets, which includes all systemically important banks.

The **retail** business model is typical to banks that use public deposits for retail lending. In Ukraine, they are characterized by a wide branches network and a high margin of main banking products.

Corporate banks focus on service for legal entities, while the share of retail is low or absent. Some of these banks, including the those with foreign capital, perform classical corporate and investment activities, while others during the pre-crisis period were captive, lending to related non-financial corporations or conducted semilegal scheme operations without any retail activities.

RF-CL or "retail finance to corporate lending**”** banks can be called typical Ukrainian banks during the pre-crisis period. RF-CLs base their business model on retail financing, transforming the proceeds into mostly corporate loans that were often provided to related parties.

Frozen banks are similar showing low business activity due to the anomalous share of equity and a low amounts of working assets. Banks in this cluster are either so-called bank-licenses, or previously active banks, which for certain reasons reduced their business activity.

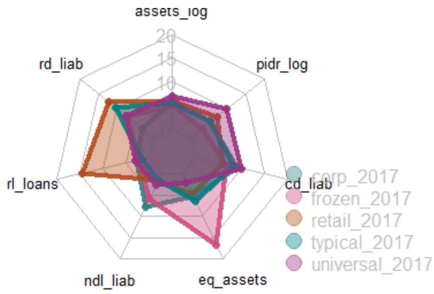

Fig.1. Comparison of business model clusters, 01.10.2017

As the result of systemic risk realization in 2014-2017 the largest number of failed banks is observed in the RF-CL (typical Ukrainian) cluster, that indirectly indicates a lower financial sustainability of particular business model under the systemic shocks. (see Fig. 2). Thus, of the 77 banks that belonged to this business model in 2014, 46 became insolvent during crisis, and 25 banks remained in this cluster.

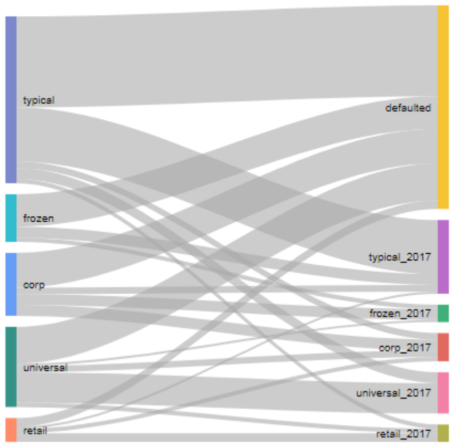

Fig.2. Migration of Ukrainian banks' business models during 2014-2017

From the cluster of frozen banks, 68% were withdrawn from the market by 2017, proved to be the least adaptable to the systemic risk business model. A rather high level of default is recorded in corporate (55%) and universal (46%) clusters. Apart from liquidated banks, a significant part of banks remained within their clusters. However, the cluster of corporate banks was a rather mobile business model during the crisis, of which only 17% retained the business model by 2017, while 17% were in the frozen cluster and 10% were RF-CL. Such process can be explained by the high share of private local banks in the corporate cluster, which were forced to close down their business or request retail financing during the crisis.

The configuration of the banking system changed under the influence of the systemic crisis, due to the cleansing policy of the NBU and the insolvent banks defaults. Despite the active migration of banks between clusters over the investigated period, the share of each cluster in the overall structure has not faced radical changes (see Fig. 3).

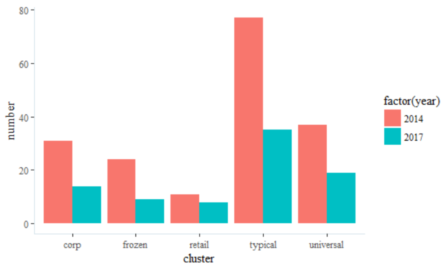

Fig.3. Quantities of Ukrainian banks' business models during 2014-2017

As of 2014, the largest cluster in terms of the number of banks was RF-CL, the second place was shared by universal and corporate. The relatively high share of frozen banks, which at the beginning of the crisis was more than 12%, during the post-crisis period declined to 8%.

In spite of the comparatively large amount of banks in RF-CL cluster, its share in total assets in the Ukraininan banking system (UBS) was only 11% at the beginning of the crisis, and at the end of the crisis had fallen to 3.2%, which is almost in 4 times. The reason is that such business model has historically been popular among small local banks involved in related-party lending (see Fig. 4).

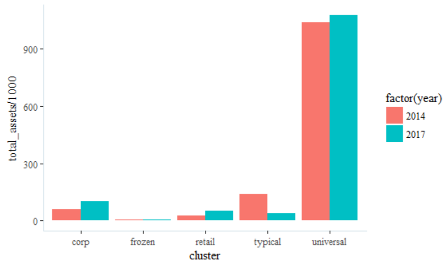

Fig.4. Net Assets of Ukrainian banks' business models during 2014-2017, UAH mln

The assets of universal banks cluster are 84% (81% before the crisis) of the assets of the Ukrainian banking system, mainly due to the public and foreign owned system-forming banks that have diversified structure of financing and credit activity. Banks belonging to the frozen cluster do not have a significant impact to the UBS, given that their aggregate market share is close to zero.

As comparative analysis showed in the pre- and post-crisis periods, the most viable model was retail banking in terms of aggregate asset growth (+ 84%) and the lowest number of defaulted banks (-27%). The second most resistant to systemic shocks was corporate model, its assets grew by 69%, despite the 55% decline in amount of banks. The least sustainable models were frozen and RF-CL, with the largest reduction in the number (by 62% and 54% respectively) and assets (-47% and -71% respectively) in the process of cleansing the UBS and the realization of systemic risk.

In the process of research, 2 banks from the frozen cluster left the banking market on the initiative of owners without termination of a legal entity. They revoked the banking license, which is an additional confirmation of the sufficient predictive ability of the proposed methodology for cluster analysis of business models of banks.

4.2 Financial Performance

The next stage of the study is the analysis of the effectiveness of the identified business models according to return on assets (ROA), net interest margin (NIM), cost-to-income ratio (CIR).

As we see in Figure 5, after the crisis, the average efficiency of banks (median ROA) increased for retail, corporate, universal and partly to RF-CL business models. Consequently, we can state the positive effect of the regulator's cleansing policy, since financially stable banks remain on the market and the overall efficiency of the banking system has increased. However, it should be noted that the variability in the distribution of activity performance in terms of ROA has become wider in all business models, indicating incomplete overcoming the crisis consequences for a number of banks, regardless of the business model.

The only business model which efficiency has not risen is frozen, with ROA indicator of the vast majority of the banks banks were in a negative zone.

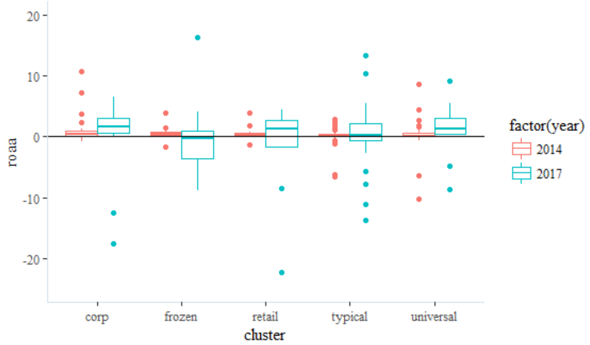

Fig.5. Return on Assets (ROA) by business models at 2014 and 2017

By results of the crisis and recovery, Net Interest Margin (NIM) grew in all business models. For the retail cluster, this was due to the possibility of developing a high-margin business, characterized by high effective interest rates due to the demand of consumer loans recovery in 2017 (see Fig. 6).

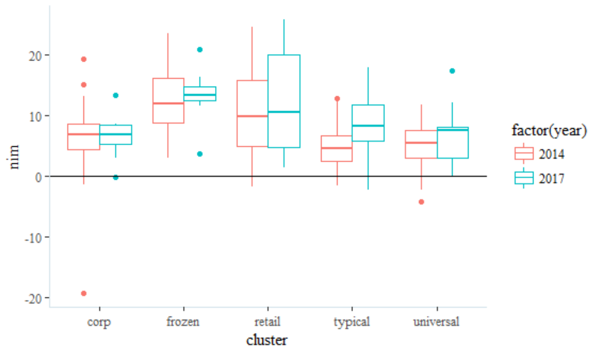

Fig.6. Net Interest Margin (NIM) by business models at 2014 and 2017

The maximum growth of the median NIM in the RF-CL cluster contributed to the general trend of deposit rates declining over the period 2016-2017. In addition, the cleansing of the market from high risk banks that offered high rates had the greatest impact on this cluster of banks, thus contributing to the growth of the average margin. Relatively insignificant growth and an absolute level of NIM are observed in a group of universal banks. This cluster consists of large, low interest income state banks that avoided cleansing due to big to fail considerations, while retaining a significant proportion of toxic assets and impossibility to reduce interest rates on deposits. The second component of this cluster is large foreign and part of domestic private banks that during the operation period accumulated significant amounts of NPLs. In the absence of new lending opportunities due to the lack of high performance borrowers, they favored investments in lower yielding government bonds, which adversely affected their interest margin.

The abnormally high NIM for the frozen group of banks can be explained by low funding costs due to high equity share and absence of toxic assets compared to banks from other clusters.

During the observation period, there was a general increase in the efficiency of interest expenses, expressed by the decrease of Cost-to-Income Ratio (CIR) for all clusters. The largest drop due to the effects of recovery from the systemic crisis and cleansing policy was the CIR of RF-CL, which median dropped by 20 % below the 50% level. (see Fig. 7).

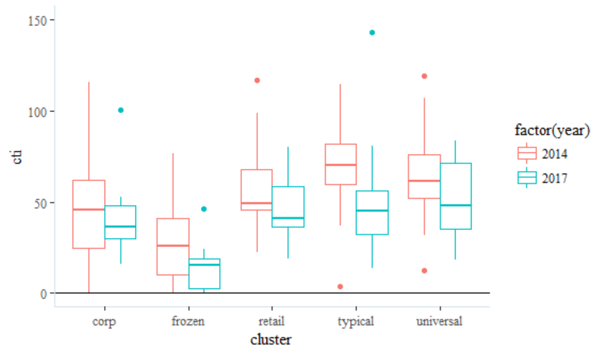

Fig.7. Cost-to-Income Ratio (CIR) by business models at 2014 and 2017

The best CIR indicators are observed in groups of corporate and retail banks, which confirms the higher efficiency of costs of specialized business models versus universal ones. The minimum cost-to-Income Ratio in the group of frozen banks is due to the low cost of borrowed capital, given its negligible share in the structure of liabilities.

As a result, the findings of financial performance show that the returns of banks, net interest margins, as well as cost efficiency across all business models have increased since the financial crisis and post-crisis recovery during 2014-2017. The effectiveness of the retail-oriented and corporate banks appeared to be the highest after financial crisis, while the greatest positive changes in the average returns occurred in the RF-CL cluster, where median values of the most effectiveness indicators became closer to the figures of the other clusters.

The main drivers of the higher efficiency for the Ukrainian banks was the effects of concentration, consolidation and cleansing processes, which enhance the most solvent banks among survived financial institutions in 2017 recovery period in spite of huge systemic shocks and loan portfolio losses in 2014-15. The results of the cost-cutting measures, disappearing of adverse herd behavior in retail deposit market and stabilization of inflation period have been sufficient too during 2016-17 post-crisis.

4.3 Evolution of Risk

This part provides a risk attributes of Ukrainian bank business models since banking system crisis. The key risk indicators that are discussed are Capital Adequacy Ratio (CAR), Cash-to-Assets Ratio, Loan Loss Provision Ratio (LLPR).

As a result of the post-crisis recovery, most survived banks (with the exception of some universal ones) managed to increase the Capital Adequacy Ratio, which was under great pressure during the 'perfect storm' period. One of the reasons for improving the capital adequacy ratio as a whole for each cluster was significant structural changes in the banking system, after which the market left about a hundred mostly undercapitalized banks. On the other hand, stress-testing, the strengthening of regulatory capital requirements and the revaluation of credit risk have been driven by the process of previously noncollectible pre-capitalization and the formation of reserves for a deteriorated loan portfolios, which was the result of an increase in own capital at the background of stabilization or even reduction of net volume assets.

The Capital Adequacy Ratio suggests that the retail and corporate oriented banks, as well as “retail funding for corporate lending” financial institutions have significantly higher median risk weights than the most of universal banks (see Fig. 8).

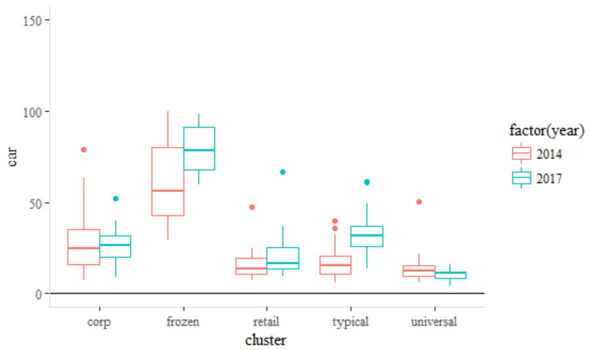

Fig.8. Capital Adequacy Ratio (CAR) by business models at 2014 and 2017

The comparatively lower equity of universal banks is the result of the scale effect due to the need for significantly higher levels of capitalization to cover bad loans accumulated by systemically important banks and other major players in the lending market. The lower share of equity capital in the liabilities of large universal banks contributed to the cherry-picking effect on the deposit market. After all, foreign and state banks, forming the basis of a universal cluster, were considered depositors as 'safe haven' in the period of system turbulence.

It should be noted that the abnormally high capital adequacy of the group frozen banks and some part of RF-CL banks is difficult to call positive characteristic due to the lost opportunity to generate net interest income. The key causes of the abnormally high CAR are: a) the absence of an effective business model for most small banks to expand active operations and exit the "frozen" state or old circuitry or captive activity; b) low opportunities for attracting deposit and loan resources; (c) the need for a larger capital buffer to protect against risks; d) compliance with regulatory requirements of the regulator regarding the minimum amount of capital and preparation for loan reservation on the consequences of diagnosing the quality of assets; e) the withdrawal from the market of many poorly funded banks during the period of purification, which provokes the growth of average capital adequacy values for these clusters [Kornyliuk (2017)].

The liquidity ratios of RF-CL business models are slightly higher than corporate and retail-oriented models, which may indicate their higher sensitivity to deposit outflows during a bank run (see Figure 9).

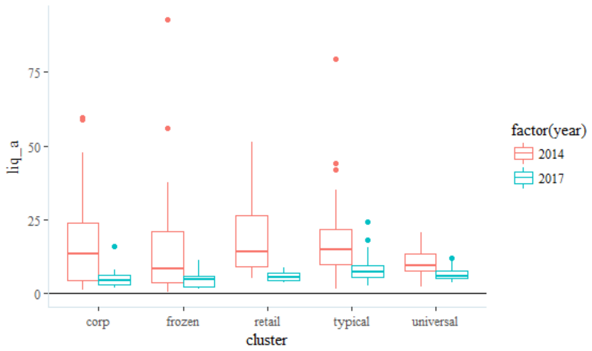

Fig.9. Cash-to-Assets Ratio by business models at 2014 and 2017

In general, the Cash-to-Assets Ratio dropped significantly from 2014-2017 by all business models. We are inclined to explain both the influence of the deposit panic and the development of the Ukrainian market of highly liquid assets such as government bonds and NBU deposit certificates, which are in much higher demand among banks than at the beginning of the crisis. From Fig. 9 it is clear that after the crisis, the market had left numerous banks with an abnormally high Cash-to-Assets Ratio, which in early 2014 more resembled "bags of money" for their beneficiaries, not financial intermediaries. After the crisis at the end of 2017, the overall level of security of high-liquid assets though decline, remains quite sufficient for classical banking.

Loan Loss Provision Ratio (LLPR) increased significantly by each business model during crisis and recovery periods because of huge rise of NPLs and more strict provision requirements (see Fig. 10).

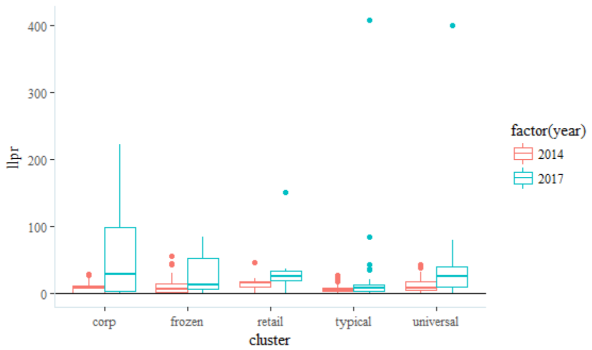

Fig.10. Loan Loss Provision Ratio (LLPR) by business models at 2014 and 2017

The most of retail, corporate and universal banks took the highest loan loss provision, while some RF-CL banks even released provisions. During the banking crises, the banks with state and foreign shareholders took the highest provisions, while the local private investors booked lower loan loss provisions because of recession and bad performance indicators of related non-financial business structures. There are a lot examples of such loan poss provision *minimizing* activity: from Privatbank before its nationalization (LLPR= 16,6% in 01.10.2016, which jumped to 294,4% in 01.01.2017) to the wide range of previously defaulted oligarchic banks, such as Delta (8,6%), Finance&Credit Bank (7,5%), Brokbusinessbank (2,1%), VAB Bank (4,7%) etc.

Summarizing our analysis of the risk indicators of the main business models of Ukrainian banks during the periods of systemic crisis, cleansing and post-crisis recovery, it can be argued that most of the banks that managed to withstand shocks at the end of 2017 are more financially sustainable than before the crisis. This is generally expressed by a higher level of equity and credit risk reserves, especially for banks with a clear corporate and retail business model.

However, there remain a lot of problem areas that require further solution in order to minimize systemic risk:

- in the group of universal banks - despite the successful up-grading and high loan portfolio reserve, the largest systemically important banks accumulated excessive amounts of NPLs, which become a source of future state budget spending for the state financial institutions and reduced opportunities for growth and strategic interest from private international investors to foreign banks;
- in the group of RF-CL banks, the intentional minimization of the amount of credit risk and adequate deductions in credit reserves is obviously indicate the lack of willingness or ability of local affiliated parties to strengthen the funding of their banking business at the expense of income from non-financial corporations.
- in the group of frozen banks - abnormally high CAR or LLPR figures indicate low credit and deposit activity and the absence of an effective business model that is capable to generate stable cash flow.

5 Conclusions

Our research of Ukrainian banking sector business models assesses the banking system structure through the changing financial and supervisory environment during 2014-2017 period. We gained new insights into the impact of different forms of business models to banking system stability. For example, we analyse the relation between Ukrainian banks business models and financial performance, risk profiles and response to anti-crisis regulatory policy through five identified clusters.

The majority of Ukrainian banks were predominantly a mix of universal and RF-CL. The core of the biggest (according to net assets) universal bank cluster is the state banks with problem with toxic assets and low quality of corporate governance. Another part of universal business models are foreign banks and the largest local ones. Despite their quantity, RF-CL banks became less powerful and systemically influential than universal group. This cluster reduced more after cleansing policy, improved its indicator to some extent, but their risk profile remains unstable. Main problems: deficit of funding (both from shareholders and depositors), higher sensitivity to regulatory pressure, lack of clear business strategy (small size – great costs).

Retail and particularly "non-scheme" corporate bank business models were the most sustainable compared with RF-CL type of banks. Frozen banks are the most likely candidates for the exit, as evidenced by the experience of previous years.

Further monitoring of Ukrainian bank business models is extremely important to develop our knowledge of this concept, to measure impact of external shocks on different types of banks and, finally, to detect the formation of systemic risk related to inherently unsustainable banking strategies.

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Appendices

Table 1. Descriptive statistics for the business models clusters of Ukrainian banks, 01.10.2017

		Retail loans to total loans (%)	Retail deposits to liabilities (%)	Non-deposit resources to liabilities (%)	Equity to assets ratio (%)	Net Assets (log)
Universal	Mean	14.55	36.56	13.03	10.22	17.20
	St.dev.	12.92	15.72	10.40	2.74	1.14
	Min.	0.46	0.04	2.01	4.11	15.72
	Max.	42.98	71.96	43.54	16.09	19.36
Retail	Mean	72.60	61.20	7.85	24.28	15.08
	St.dev.	19.91	17.36	6.32	19.12	1.06
	Min.	42.77	41.85	1.83	9.76	13.57
	Max.	97.34	89.39	22.40	66.71	17.28
Corporate	Mean	12.95	14.84	36.72	26.56	14.87
	St.dev.	22.74	14.77	26.99	11.60	1.41
	Min.	0.00	0.00	2.28	9.18	12.65
	Max.	71.06	42.66	76.38	52.09	17.52
RF-CL	Mean	7.35	49.77	7.66	32.20	13.75
	St.dev.	8.95	14.31	6.03	12.18	0.64
	Min.	0.14	28.45	1.03	13.68	12.89
	Max.	35.52	92.08	21.82	61.57	15.19
Frozen	Mean	10.07	30.85	32.61	78.86	12.69
	St.dev.	10.09	17.57	20.29	13.87	0.72
	Min.	0.00	0.00	6.26	59.64	12.00
	Max.	27.10	52.83	70.89	98.02	14.60

Table 2. Dynamic of assets and quantity of Ukrainian banks by business models in 2014-2017

Business model	Assets, UAH mln, 01.01.2014	Assets, UAH mln, 01.10.2017	Change of assets, %	Number of banks, 01.10.2017	Number of banks, 01.01.2014	Change of number, %
Universal	1 039 430	1 078 833	3,8	37	19	-48,6
Retail	28 501	52 603	84,6	11	8	-27,3
Corporate	61 062	103 281	69,1	31	14	-54,8
RF-CL	140 528	41 008	-70,8	77	35	-54,5
Frozen	7 988	4 270	-46,5	24	9	-62,5

Innovative Complex of Information and Technological Support of Professional Training in Smart Cities

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Abstract. It is proposed the training process of qualified specialists in accordance with the needs of a person and the requirements of the labor market in the smart city to be presented in the form of five consecutive functional stages: determination of professional inclinations and abilities; monitoring of the urban labor market; a choice of the future profession; a choice of educational institution; formation of an individual learning trajectory.
The paper provides the description of the architecture developed by the authors and the processes of main modules of the program and algorithmic complex of information and technological support for the training of specialists in smart cities. The peculiarities of program realization are revealed as well as the system functioning and the technical characteristics of the software product.

Keywords: smart city, OLAP, hypercube, knowledge potential, career orientation test, web application.

1 Introduction

In modern information society, an innovative type of social existence is formed, where everyone is technologically and institutionally guaranteed the effective implementation of two important information processes: the first one is free creation and dissemination, and the second one is receiving and processing of information [1, 2].

The formation of this social system led to a series of information and technological transformations and generated new tasks, the solution of which is possible only in the context of interdisciplinary research related, in particular, to the formation of high-tech social and communication environments in the cities that are actively turning into social polis with complex infrastructures [3]. These infrastructures need to be effectively shaped, developed, modernized and adapted to the needs of communities. One of the effective concepts of implementing such approach is the concept of smart city, which provides a radical reorganization of all life spheres in the city, including the social and communication environment based on modern information and communication technologies [4, 5]

According to the analysts, the city can be defined as smart provided that investments will focus on the training of a highly educated workforce, which serves as a main driver of the city's innovative development. As a result, a new transformational paradigm has been formed, which IBM experts call the educational continuum, which includes: life-long learning technologies, data analysis for student and institutional data and performance indicators, personalized learning trajectories, the use of the acquired competences for the development of the economy and the growth of the city potential as a whole.

A significant number of large and small cities in the world use this innovation to implement projects that ensure their development with the introduction of intelligent digital information, communication networks and technologies. This, in turn, requires the development of unique innovative models of the hyper-complex system, which is a modern city, taking into account historical, mental, religious, political and economic peculiarities, and conducting systematic research on an interdisciplinary platform [6].

The city's social and communication environment is formed and functions in a complex system of information flows, where on the basis of modern communication networks, information and communication technology complexes, processes of creation, processing, storage and transmission of information between subjects that communicate take place. It combines medical, educational, cultural, scientific institutions, structures of municipal government, mass media, and others [7-10].

In such conditions, the need to develop a software and algorithmic complex that would implement the basic principles of information and technology support of the qualified specialist training in accordance with the needs of an individual and the requirements of the labor market in a smart city becomes evident.

The **purpose** of the paper is to formulate a set of requirements, system functional characteristics, analysis, architecture construction and program implementation of the software and algorithmic complex of information and technological support of specialist training in accordance with the needs of an individual and the requirements of the labor market in smart cities.

1.1 Related Work

Information systems that are used today to accompany the profession choice in cities are not effective enough. In particular, there is practically no possibility in one information point to analyze information about a person as an object of vocational and educational work and to obtain comprehensive information and analytical data of the regional labor market and educational services. Information is mainly provided without proper adequacy and structuring.

Information sources about the vocational orientation of the World Wide Web are divided into integrated and independent web pages.

Integrated web pages are pages of professional counseling organizations and institutions. They contain both general and specific information for this institution.

Independent web pages are non-interlinked web pages that include information about vacancies, professions, educational offers for schools and higher education institutions, work offers with company descriptions, as well as they assist in making decisions about choosing the future profession or about its change.

According to the functional purpose, information technologies focused on providing solutions to the problems of professional orientation of young people can be conditionally divided into the following classes:

The sites of educational institutions that inform about the terms of the entry and training directions, aimed, above all, at encouraging graduates to enter this or that higher educational institution. Such resources are not oriented to maintaining the processes of individual choice of profession, they do not give grounded advice to an entrant, but instead they create uncertainty about the profession, as a young person hesitates about several equal or similar options for choosing a possible specialty.

Educational portals. This type includes resources that contain comprehensive information on all aspects that relate to education in general. However, such sites do not provide clear advice for people who choose a profession, they do not give an opportunity for objective testing on the subject of professional orientation.

Resources of employment. This type of Internet resources is the most widespread among similar tools. As a rule, they can help you to get information about the list of vacancies, their features and additional requirements, the presence of vacancies in different regions, as well as to establish contact with an employer. The disadvantage of such IT is a lack of information about educational institutions, where it is possible to obtain the relevant profession, re-qualify or get a second higher education.

Test resources. This type of IT offers a considerable selection of different psychological tests that relate to the choice of profession. As a rule, their main drawback is that they do not contain information on the further direction of the profession search, that is, educational institutions, aspects of a profession, prospects of employment, the need for a profession in our time, etc.

The results of the comparison of the functional characteristics of existing foreign and domestic online resources of professional orientation are presented in Table 1.1, the analysis was conducted by the following parameters:

P_1 – definition of professional type of personality;

P_2 – examination of the urban labor market;

P_3 – recommendations for choosing a profession (according to the professional abilities and the required professions);

P_4 – examination of educational institutions functioning in the city;

P_5 – selection of educational institution according to chosen profession;

P_6 – the possibility of forming an individual learning trajectory (according to the level of knowledge potential).

Table 1. Comparative analysis of online resources

Resource name	**Evaluation was carried out using the following parameters**					
	P_1	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**
SC Accelerate (USA)	+	+	+	+	+/-	+/-
Hobsons (USA)	-	-	-	+	+	+/-

Career Choice GPS (Canada)	+	+/-	+	+/-	+	+/-
Smartie (Russia)	+	-	+/-	-	-	-
My career (Ukraine)	+	-	+/-	+	+/-	-
Career (Ukraine)	+	+	+/-	+	-	-
Education .UA (Ukraine)	-	+/-	-	+	+	-

The analysis allows us to claim that the implemented software and algorithmic complex of information and technological support of the specialist training processes combines the main stages of specialist training taking into account the needs of an individual, economic and social development, and the requirements of the labor market in the city, community or region, as well as the systemic aspirations of the communities. And because of its functionality it is perhaps the most complete representation of the vital functions of such systems

2 Complex of Information and Technological Support of Professional Training

2.1 Specialist Training in Smart Cities

The process of qualified professional training in accordance with the needs of an individual and the requirements of the labor market in the smart city is a complex, multistep, iterative process that requires consideration of a large number of parameters and prerequisites. It can be expanded in five consecutive functional steps: **stage 1** is the definition of professional inclinations and abilities; **stage 2** is the labor market monitoring in order to determine the trends of changes in the factors affecting the supply and demand of the workforce; **stage 3** is the choice of a future profession; **stage 4** is the choice of educational institution; **stage 5** is the formation of an individual learning trajectory (ILT).

On the basis of the above sequence of specialist training stages, the Diagram of using options (Fig. 1) of the software and algorithmic complex of information and technological support for the specialist training processes with external entities (user, administrator) and the requirements to the basic functions of the developed software and algorithmic complex was formed.

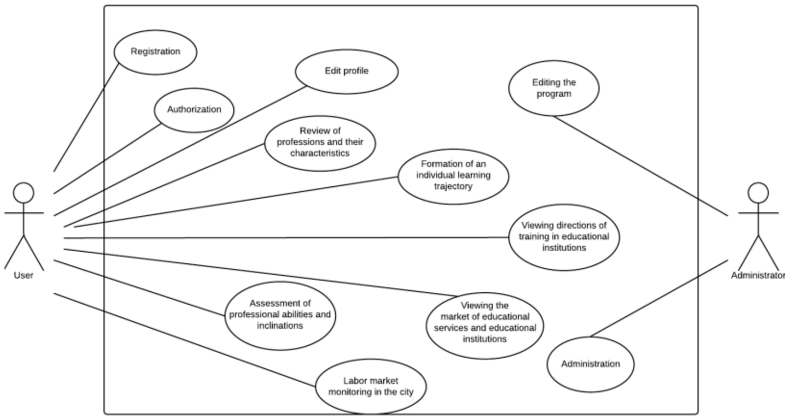

Fig. 1. Diagram of the using options of the program and algorithmic complex of information and technological support for the specialist training processes in accordance with the needs of an individual and the requirements of the labor market in the city

The main actors (an administrator and a user) are selected, users can be a person who makes decisions on their professional orientation (the entrant), their parents, employers, specialists of employment centers, and others. Actor User uses a system to monitor the labor market in the city, review information about educational institutions operating in the city, as well as to determine the professional abilities and to receive recommendations on the choice of profession and, accordingly, the revision of the system generated by an individual learning trajectory. Actor Administrator controls the technological aspect of the functioning of the software and algorithmic complex as well as monitors and eliminates possible errors or failures in the system.

2.2 Architecture of Software and Algorithmic Complex

The software and algorithmic complex of information and technological support of the processes of specialist training in accordance with the needs of an individual and the requirements of the labor market in a smart city is developed on the basis of three-level architecture (Fig. 2). This enabled to split it into separate interrelated parts, which divide the system functions and separate the user interface from the data.

Administration subsystem. The administration subsystem contains the following components: access right distribution module, user profile support module, identification and authentication module, and test support module.

The *access right distribution module* provides the user, in accordance with the rights of access, the ability to work in the available modes to them (to undergo testing, review vacancies, look at the city's educational institutions, etc.).

The *user profile support module* allows you to create, edit and delete user profiles.

The *identification and authentication module* provides the user with a possibility to enter login and password and establish the user's correspondence with the identifier provided to him.

The *test support module* allows you to add, edit and delete tests oriented to defining the vocational orientation (Holland and Yovashi tests) as well as tests for identifying the person's knowledge potential.

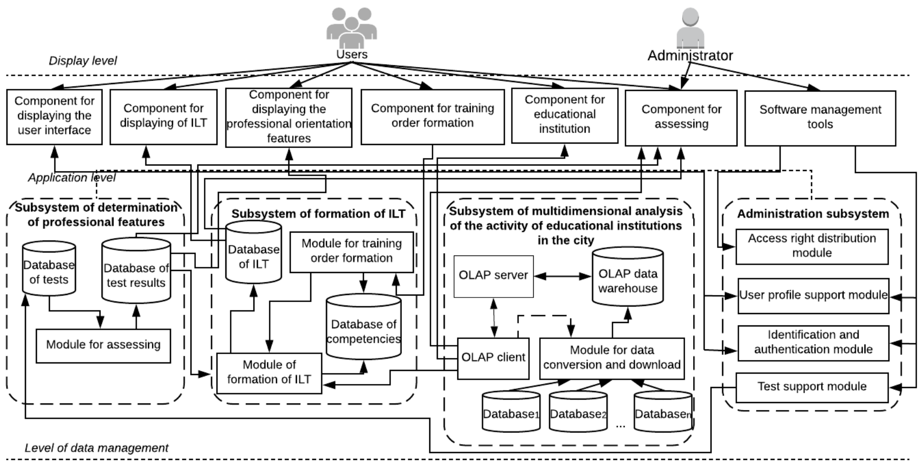

Fig. 2. Architecture of the software and algorithmic complex of information and technological support for the specialist training processes

Subsystem of the multidimensional data analysis. The subsystem of the multidimensional data analysis concerning the activities of the educational institutions in the city consists of OLAP data warehouses, data conversion and download module, OLAP server and OLAP client. The OLAP warehouse contains the source data for the analysis of the activities of educational institutions. The data structure is multidimensional and adapted for OLAP analysis. The main function of the module for data conversion and download is the formation and maintenance of relevant data in the repository.

The OLAP server performs operations to process queries for multidimensional data, as well as to ensure the counting and storage of aggregate (total, average, etc.) values.

The OLAP *client* displays the data received from the OLAP server in a user-friendly mode.

Developing data warehouse of software and algorithmic complex there were created multidimensional data cubes of different degrees of complexity [11]. In Fig. 3 a diagram of the multidimensional analysis process of an educational institution functioning is shown.

Data hypercube is not analyzed in all dimensions at the same time. Typically, a data sample from a hypercube is made for the specific values of a particular set of measurements, and as a rule, one or two measurements are left to be free, using which further analysis is carried out.

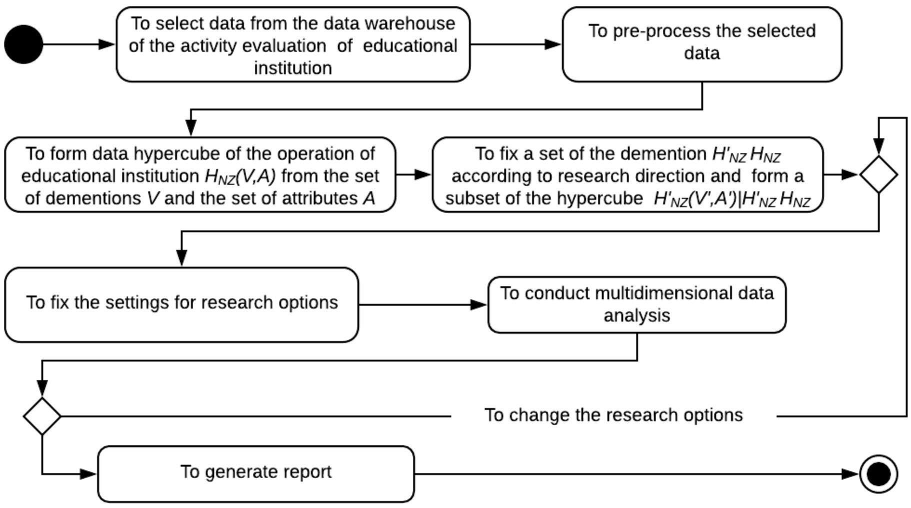

Fig.3. Diagram of the multidimensional analysis process of an educational institution functioning

The subsystem of determination of professional features allows users to define their professional inclinations, abilities and to choose a field of professional activity, includes a database of tests, a module for assessing and a database of test results [12].

The *database of tests* is intended for the storage of vocational guidance tests of Holland and Yovashi [13].

The *module for assessing the results* processes the test results and writes them to the database of test results.

Subsystem of formation of an individual learning trajectory. The subsystem of formation of ILT allows to create individual learning trajectories of users, includes the module for the formation of a training order, a database of competencies, the module for the formation of ILTs and the database of ILT.

The *module for training order formation* gives an opportunity to download from the server the reporting information and analytical and statistical materials of the city employment centers (information about the need of the city in the workers of one or another sphere) and save them in the database of competencies.

The *module of formation of ILT* creates individual learning trajectories for users on account of the implementation of diffusion-liked models of the knowledge potential dissemination developed by the authors in the educational social and communication environment in the smart city. The authors proposed and worked out variants of solving the problem of modeling the component interaction of the knowledge potential of different agents within the given clicks, as well as introduced a multicomponent vector of the knowledge potential (solving the corresponding problem for the system of different equations) and presents the results of numerical experiments [14]. In the case when each k user (agent) is characterized by two knowledge potentials $\varphi_{l,k,m}$ ($l=1,2$, for example, potentials characterizing mathematical knowledge and language of k agent at the m moment of time, a model describing the redistribution of these potentials taking into account possible influences of one of them on another one (for example, obtaining a high knowledge potential in mathematics can affect the reduction of the knowledge potential of the language for a given object, or vice versa, positive interactions), appears in the form:

$$\begin{cases} \varphi_{1,k.m+1} = \varphi_{1,k,m} + \sum_{i=1}^{k_j} \alpha_{1,k,i}(\varphi_{1,k,m} - \varphi_{1,k,i}) + f_{1,m} + g_{1,m}(\varphi_{1,k,m}, \varphi_{2,k,m}) \\ \varphi_{2,k,m+1} = \varphi_{2,k,m} + \sum_{i=1}^{k_j} \alpha_{2,k,i}(\varphi_{2,k,m} - \varphi_{2,k,i}) + f_{2,m} + g_{2,m}(\varphi_{1,k,m}, \varphi_{2,k,m}) \end{cases} \quad (1)$$

where, $f_{1,m}$, $f_{2,m}$ are the intensity of the sources of knowledge transfer, $g_{1,m}(\varphi_{1,k,m}, \varphi_{2,k,m})$, $g_{2,m}(\varphi_{1,k,m}, \varphi_{2,k,m})$ are functions that characterize the interdependence (mutual influence) of studying in this case, mathematics and language.

Similarly, in the case when objects (agents) are characterized by many potentials, that is, $l = 1,2,\ldots,l_*$, we have:

$$\varphi_{l,k.m+1} = \varphi_{l,k,m} + \sum_{i=1}^{k_j} \alpha_{l,k,i}(\varphi_{l,k,m} - \varphi_{l,k,i}) + f_{l,m} + g_{l,m}(\varphi_{1,k,m}, \ldots, \varphi_{l*,k,m}) \quad (2)$$

The algorithms of the corresponding numerical calculations for forecasting situational states presuppose their use in creating individual learning trajectories of users taking into account abilities, interests and opportunities.

In Fig. 4 there is a diagram of activity characterizing the process of identifying a multicomponent knowledge potential in order to form an individual learning trajectory. The inputs are the initial distributions of various types of knowledge potentials of agents, weight ratios, as well as the intensity of sources of knowledge distribution.

The *ILT database* provides the storage of generated individual learning trajectories of users for further analysis and use.

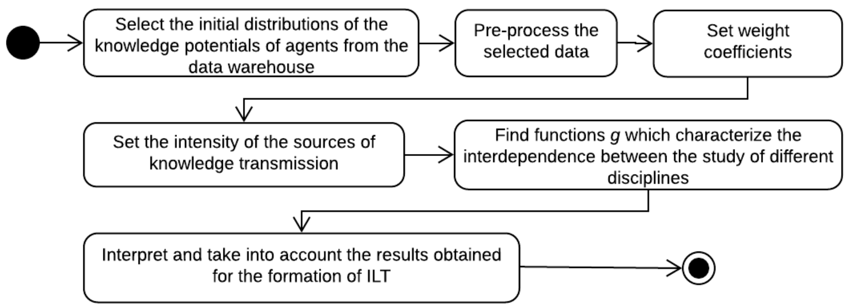

Fig.4. Diagram of activity of ILT formation

3 Principles of Software and Algorithmic Complex Functioning

The software and algorithmic complex of information and technological support of the training processes of qualified specialists in accordance with the needs of the individual and the requirements of the labor market in the smart city is developed in the form of a single-page application (SPA), which has several advantages: a rich functional interface ; quick reaction of the interface, due to the lack of need to contact the server at each action; a significant reduction in the load on the server; significant simplification of the logic and complexity of the server.

The architecture of the web application is designed on the basis of client-server technology, which allows you to work both locally and in network mode. The server part is written using the Vue.js environment and JavaScript framework that uses the MVVM template to create user interfaces based on data models through reactive bindings.

For users, the following modes of the web application function are defined: definition of professional abilities; review of vacancies; review of educational institutions in the city; career choices; viewing of an individual learning trajectory; administration. You can go to each of the modes by selecting the appropriate tab.

The admission of a user to work with a software and algorithmic complex involves the implementation of procedures for authorization or registration, the last one must necessarily be carried out with the introduction of such data as the city of residence, education level and birth date in order to their further multivariate analysis.

After authorization, users are given an opportunity to determine their professional abilities and inclinations through passing the vocational guidance test (different professions are presented in pairs; in each pair of professions one should be preferred).

To visualize and interpret the results of vocational guidance testing of users in the software and algorithmic complex, the procedures are developed such as Process, Prepare, Calculate, the program code of which is given below:

```
function CalculatePollResult(Poll poll, Collection us-
erSelectedVariants)

{
  Collection pollResultItems = fetchAllPollResultItems-
FormDB(poll)
  foreach pollResultItem in pollResultItems
      foreach userSelectedVariant in userSelectedVariants
          if userSelectedVariant.resultItem is equal to
pollResultItem
              add one point to pollResultItem.points
          end if
      end foreach
  end foreach
  foreach pollResultItem in pollResultItems
      if pollResultItem.points is equal to 0
          remove pollResultItem from pollResultItems
```

```
    end if
  end foreach
  return sortResultItemsByPoints(pollResultItems)
}
```

For example, Fig. 5 illustrates and interprets the results of the method of determining the professional type of personality.

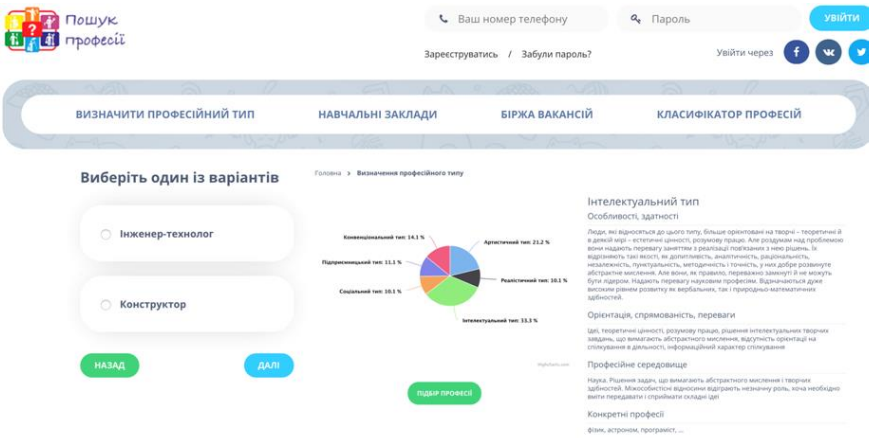

Fig. 5. Results of determining the professional type of personality

After completing a vocational guidance test, the opportunity to review vacancies (taking into account the needs of the city of the specialists) is given with the maximum of their compliance with the professional inclinations and abilities of a person identified as a result of testing, as well as the city's ability to ensure their training, that is, the availability of educational institutions that educate specialists for the chosen direction.

It should be noted that for a faster and more reliable implementation of the software product a set of independent components is formed, each of which performs own functions. This is in particular the component of job search for a specific professional type of personality.

4 Conclusion

The architecture of the software and algorithmic complex of information and technological support of the training specialist processes in the smart city is developed. Information is given about the main software modules of the software and algorithmic complex, the levels of display, application and data management are highlighted. Diagrams of multidimensional analysis of educational institution activities and process of determination of multi-component knowledge potential for formation of individual learning trajectories of agents are given. The software and algorithmic complex is developed in the form of a one-page web application, which gives it signs of mobility and simplifies the implementation of data updating processes.

At the present time, the testing of the developed software and algorithmic complex is carried out on the basis of the city of Ternopil. Full-scale database filling and system debugging of all components of the complex is being implemented. Full-scale testing of the system in real conditions of the admission campaign to the university on the specialties of the educational branch Information Technologies is scheduled on May-August 2018. At the same time, analytical assessments of educational experts and representatives of firms - employers in the IT industry confirm previous positive feedback on the completeness, integrity and efficiency of the proposed architectural solutions of the system.

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GIS Based Model of Quotas Regulation and its Impact on the Extraction of Ecosystems' Natural Resources and Social Welfare

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Abstract. Research goal of the paper is to study ecosystem using Geographical Information System (GIS) based technology to develop valid recommendations for sand extraction from water body. Our subject of research is GIS Based Model of Quotas Regulation and its Impact on the Extraction of Ecosystems' Natural Resources and Social Welfare. We used such methods as optimization methods, GIS methods, differential-equations method, marginal benefit-cost analysis. An example of mathematical model for determining of ecological equilibrium during sand extracting in the ecosystem is developed using Google Maps. The influence of economic activity due to sand extraction on fish fauna is described. The GIS based ecological-economic model is developed on the logistic model basis for establishing regional quotas for extraction of natural resources during economic activity in the southern Ukraine. Regulatory economic mechanism of natural environment is proposed. It implies such quota for sand extraction from water body, which does not lead to deterioration of the natural environment and stimulate the increase in social welfare.

Keywords: GIS technology, ecosystem, quota regulation, externality

1 Introduction

The surrounding world can be divided into three components: nature, human society and economics. Humanity provides its livelihood by developing an economy, which, in turn, functions through the consumption of tangible and intangible resources, creating negative and positive external effects. Improvement of humanity`s well-being should not occur due to excessive consumption of non-renewable natural resources, but through the creation of incentives for the population to create their needs in accordance with available natural resources, which is proclaimed the main idea of the balanced development of world society by the United Nations. There is a new function of the state – ecological, which is aimed to harmonize the interests of society and nature, ensure optimal consideration of economic and environmental interests by means of GIS. Implementation of the economic mechanism of nature management implies such a load of economic activity, which does not lead to undesirable consequences in biota and does not lead to deterioration of the quality of the environment.

It is possible to follow the changes in ecological balance, the reaction of individuals and the entire ecosystem community, expanded in time and space, with the help of mathematical research methods. Today there is a wide range of applications of mathematical modeling to solve many ecological and economic problems. Moreover, the experience of using mathematical modeling does not raise any doubts concerning the efficiency of this method in the study and forecasting the natural ecosystems state under conditions of anthropogenic influence [1].

Local minerals (sapropel, gypsum, limestone, chalk, sand, loam, sandstone) belong to non-renewable natural resources, the geological rate of formation or accumulation of which is much less than the rate of human consumption. Demand for sand is increasing in many parts of the world due to rapid economic development and subsequent growth of building activities. Sand is considered a cheap resource, because businesses need to cover only the exploitation cost (costs of equipment, labor, fuel, and transport) [2]. Lack of adequate information on the environmental impact of river sand mining is a major gap, challenging regulatory efforts in many developing countries including Ukraine. Thus, a scientific assessment is a precondition in setting management strategies in the sand mining areas. Environmental impact assessment (EIA) demonstrates that the activities associated with mining and sand processing have not only affected the health of the river ecosystems but also degraded its overbank areas to a large extent [3].

The environmental effects of indiscriminate sand mining (for example, the annual catchment areas of the Vembanad lake, southwest coast of India) are considered by Padmalal D. et al [4]. The quantitative estimation of the sand mining impacts on the rate of water level reduction in the riverbed of the catchment areas of the Vembanad lake. Also rivers on the southwest coast of India are under immense pressure due to indiscriminate extraction of construction grade sand, which is the most disastrous process. The volume of in-stream mining is about 40 times higher than the sand input estimated in the gauging stations. As a result of indiscriminate sand mining, the riverbed in the storage zone is getting lowered at a rate of 7–15 cm. This imposes severe damage to the physical and biological environments of these river systems [5]. In-stream mineral mining is strongly regulated in countries such as Portugal, Italy, and New Zealand and is prohibited in countries such as France, the Netherlands England, Germany, and Switzerland.

We proposed regulatory strategies for the overall improvement of the rivers and its biophysical environment. The policy recommendations grounded in our the paper are intended as guidance to decision makers in charge of sand mining to make more informed decisions. Physical processes and biological data were collected from {data source} to analyze optimal level of sand mining regarding damage to fish and local biota. Our task is to minimize environmental effects which mitigate negative consequences for both environment and social welfare. Present study examines the impact of sand extraction on local ecology in the study area using Google Map and Google Earth as GIS techniques. Images captured by Google Map and Google Earth during 2017 have been used for the analysis.

The **purpose** of the paper is a study of ecosystem using GIS based technology to develop valid recommendations for sand extraction from water body.

The paper is organized as follows: part 2 describes related works, part 3 demonstrates ecosystem quota model; part 4 demonstrates experimental result; the last part concludes.

2 Related works

The study by Izougarhane M. et al [6] provided a qualitative and quantitative assessment of the fishery's effectiveness at the mouth of the Sebou River (Morocco) and assessment of its environmental condition. The results of the observation since 2005 and until 2016 show reduction of qualitative and quantitative indicators of fishing. In addition, it is noted that during this period there was a change in the physical characteristics of the water body, and the quality of water in the aquatic environment is assessed as contaminated and very contaminated. The author notes that the main cause of degradation of water body biodiversity is dredging.

Sowunmi F. A. et al [7] revealed significant differences from the average silt charge of river water and quantity of fish caught by fishermen during working hours in areas with dredging and without it. Low productivity in places of dredging works is due to their negative impact on the environment. In areas where there were no sand dredging works, fishermen received more extraction per day. The authors note, the need to control the activities of sand dredges in fishing communities is to ensure the sustainability of the environment,on one hand,, and the conservation of fishing in the study area on the other

The interesting results are found in works of Adesina T. K., Adunola O. A. [8]. The expected effects of dredging activities on fishing of artisanal fishermen are considered in Lagos State, Nigeria. Results of statistical studies revealed the significant relationship between the impact of sand dredging effect on fishing activities, the relationship between monthly income and perceived effects of sand dredging on fishing activities. Scientists have suggested enhancing the artisanal fishery contribution to total Gross Domestic Product (GDP), employment generation and total increase of domestic fish production.

Akankali J. A., Idongesit A. S., Akpan P. E. [9] have assessed the physicochemical parameters of water samples collected from upstream and downstream of OkoroNsit (Nigeria) stream for sand mining activities: hydrogen index (ph), temperature, turbidity, dissolved oxygen, biological oxygen demand, sulfate, nitrate, phosphate, suspended solid, calcium, magnesium, oils and grease. It was found that river water was polluted as a production result of sand mining activities at IsoEsuk River, IkotAkpaEkpu. The results of some analyzed parameters of investigated substances were within the limits of maximum permissible values, but some physical and chemical parameters and heavy metal content were higher than the permissible water quality standards.

Wilber D. H., Clarke D. G. [10] conducted the assessment of the biological effects of increased concentrations of suspended sediment caused by human activities, such as navigation dredging, on estuarine fish and shellfish. Researchers emphasize the need for managers to determine the volume of sand extraction based on the assessment of potential consequences of production activities during dredging.

Kim C. S., Lim H. S. discovered the prevalence and accumulation of sediment in construction grade marine sand in the coastal waters of Korea on the basis of a combined approach to observations and modeling [11]. Scientists used field measurements collected during mining operations in Kyunggi Bay, Korea to develop sediment parameters and source conditions for a three-dimensional (3D) sediment transport model built on the Regional Ocean Modeling System (ROMS). The model is run with realistic forcing obtained from a 9 km meteorological model, tides, and river discharges. The resulting picture of the distribution of silt charge in depth and in space corresponds to the data of field observations and demonstrates the character of distribution in accordance with the granulometric composition of the sand.

Environmental problems occur when the rate of sand extraction, gravel and other materials exceeds the rate at which natural processes generate these materials. Sand extraction destroys the cycle of ecosystems, impacts on the biological resources including destruction of infauna, epifauna, and some benthic fishes and alteration of the available substrate. This process can also destroy riverine vegetation, cause erosion, pollute water sources and reduce fish diversity. This study aims to investigate both the positive and negative impacts of sand mining: positive in terms of financial gain or social welfare and negative in terms of environmental impacts associated with potential sand mining operations: and develop the best management practices in order to minimize the adverse environmental impacts [12].

Consequently, the results of the research of world scientists proved the necessity in development of advisory and substantiated recommendations that can be obtained by using mathematical models. It is possible with using of system analysis, computer modeling to investigate more deeply the mechanism of transformation of water objects within the framework of water management works, to make plausible scenarios of the possible development of the consequences of the impact of human economic activity on the state of water resources in accordance with the plans of economic development of the regions.

Sustainability of extraction of ecosystems' natural resources depends on precise assessment of biomass resource, planning of cost-effective logistics and evaluation of possible environmental implications. In this context, it is important to review the role and applications of geo-spatial tool such as GIS for precise agro-residue resource assessment [13]. Although most conservation efforts address the direct, local causes of biodiversity loss, effective long-term consideration of ecosystem exploration will require complementary efforts to reduce the upstream economic pressures, such as demands for food, water and forest products, which ultimately drive these downstream losses [14].

Alternative economic approaches study the economy with a multidisciplinary view, considering paradigms of social inclusion, justice and sustainability. Geographic information science (GIScience) can be defined as a multidisciplinary and a multiparadigmatic field, where "spatial thinking" is fundamental. The study of environmental quality of life can be supported by the calculation of spatial indicators [15].

The externalities produced by extraction of natural resources are multidimensional, may strongly depend on the local context, and thus are difficult to capture through standard environmental valuation exercises [16]. We experiment a GIS approach to design a GIS based model of quotas regulation and its impact on the extraction of natural resources of the ecosystem and social welfare. The set of GIS-based variables (local context variables) prove to be significant predictors in sustainability of natural resources of the ecosystem. We can compute simulated values that combine information on social welfare of agents with opposite goals for use in policy choices such as infrastructure localization and negotiation of compensations.

Changes in natural resouves are complex, thus, managing an appropriate type of change to satisfy stakeholders with various interests is challenging. Two kinds of conflicts might occur as a result of change in an ecosystem: (1) conflicts among multiple ecosystem services i.e., internal conflicts and (2) conflicts among multiple stakeholders i.e., external conflicts [17]. In our paper we develop two change scenarios of fish recovery (net increasing and net decreasing).

Model enables decision makers to resolve internal conflicts while considering the relative values of multiple ecosystem services to show how well the model enables decision makers to resolve external conflicts in a group while taking into account the diverse goals of stakeholders. Obtaining acceptable change solutions among stakeholders with conflicting interests can lead us in moving from individual decision-making to group-based decision-making so that we can enhance sustainability in natural resource extracting.

Evaluation of analytical tools allows assessing the minimum amount of information needed to properly delineate stock units. Single technical approaches are insufficient to delineate complex fish stock structures [18]. GIS and hydro-economic models were used in order to delineate groundwater quality zones in the Central East of Punjab-Pakistan and observe the impact of groundwater quality on agricultural economics [19].

Mathematical models have been widely used to simulate all aspects of bioenergy production systems. Thus GIS-based approach is a powerful method to collect data, perform spatial analysis, combine and manage both spatial and attributes data inside a determinant region [20].

A GIS is used for locating the service areas of businesses and corresponding environmental conditions. For ecological models, the results suggest that on average there is a significant increase in efficiency of responsible decision and policy makers about extraction of natural resources when externalities are incorporated in the function of resources extraction. This suggests that businesses have internalized the effects of fishery decreasing and have adapted to the environment in which they operate. The results can simulate decision-making in public safety issues (design of model extraction, regulations of quotas).

We try to answer how to specifically estimate the ecological impact of sprawl of natural resources extraction using GIS and ecological valuation method. An ecological estimation method examines the economic losses of natural environmental.

3 Ecosystem Model of Quotas Regulation

Mechanisms responsible for the development of the natural system can be determined with consideration of the functioning of the biological or ecological system as the result of the interaction of their constituent and external factors. It is reflected in the change of the environment state in which these systems are considered. It is possible to thoroughly investigate the interaction of various factors through the use of mathematical methods and methods of mathematical modeling. These mathematical and simulation models can be used to test various scenarios and strategies in order to minimize ecological effects. We can charge specific quotas for sand exploitation using benefit-cost analysis, where benefit is a profit of businesses which extract sand; cost is a decreasing of fish population in monetary terms.

In the decision-making concerning the sand extraction, in particular sand and gravel material [21], the apparatus of game theory (GT) can be used. When studying and analyzing conflict issues and trying to predict the behavior of competitive players, GT approaches allow simulation of the self-centred attitude of the involved players with a fairly realistic manner. In that context, GT methods compared to other conventional methods of strategic analysis, such as linear programming, make better estimates of the game outcome. The role of GT is to propose a methodology about good governance of the mining sector that promotes a sustainable sharing of aggregate resource by securing environment and safekeeping revenues in mining trade market.

The simplest case of controlling the dynamics of a ecosystem's population is realized when the population's change rate is proportional to the deviation from its equilibrium state (Malthus model):

$$\frac{dN}{dt} = k \cdot (N - N_0) \tag{1}$$

Here fish population grows proportionally to their available quantity. The solution of the equation has the form: $N = N_0 + (N_1 - N_0) \cdot e^{kt}$, where N_1 is a deviation from the equilibrium state at time $t = 0$. For $k > 0$, the ecosystem will deviate from the equilibrium state N_0, whereas for $k \leq 0$ the system will return to its equilibrium state. The encroaching speed or removal speed will depend on the absolute value of the control parameter k. Linear models are aimed to maintain the system in its current state, whereas in the ecosystem it is often necessary to transfer the system from one state to another, which is more desirable according to certain criteria. Nonlinear models allow the system to be moved from one state to another.

Population dynamics can be adequately described by means of one independent variable quantities, and factors influencing the state of the system are taken into account in the form of given constants. One of the nonlinear models that allows this to be done is a logistic model that takes the form of the following equation:

$$\frac{dN^*}{dt} = aN^*\left(1 - \frac{N^*}{K^*}\right) \tag{2}$$

where $N^*(t)$ – number of population at the moment of time t, a – Malthusian parameter, $K*$ – ecological carrying capacity [22].

During the sand extraction, a temporary effect on the fish fauna is expected. It is manifested by the death of baby fish and fodder organisms, due to the increase of silt charge in surface waters from dredging. Dredgers form zones with significant quantities of silt charge. In addition, during soil removal, hydrobiota can suffocate and die. In the zone of high turbidity it is necessary to take into account the influence of silt charge both in the water column and on the bottom, which is especially important for spawning grounds and feeding places for young fish.

The reaction of fish during sand mining (response of biota to anthropogenic impact) manifests itself by the removal of adult individuals outside the zone of impact of the dredger immediately after the sensation of noise and vibration. Baby fish that are not yet capable to move by themselves, and caviar from the bottom and the water column will die in accordance with the increase in turbidity, that is, under the condition of continuous operation of the dugout for a long time. This may be in line with the condition of exceeding birth-rate mortality (negative ‘a’).

The inhibition of the fish fauna in the area of sand extraction has a local and temporary character and, after a while, there will be processes of natural reclamation of the organisms of the bottom fauna. Restoring of the feed base after the completion of the sand extraction is carried out for a certain time. Then the adult fish will return (some species of fish, even with certain indicators of turbidity), and the birth rate will eventually recover.

The equation (2) is integrated by the division of variables, and its solution determines the number of population at the moment of time t, has the form:

$$N^* = \frac{K^* N_0 e^{at}}{K^* + N_0\left(e^{at} - 1\right)} \tag{3}$$

where N_0 – initial number of fish in a water body.

The Ferkhyulst model is a generalization of Malthus model for existing restrictions on the extraction of natural resources. In this case, the management of the quotas for a sand extraction should be made in such a way as to achieve the maximum profit from the extraction of this sand, under condition that it is preserved for future use, and this extraction should not exhaust the catch of fish in the water body. Alternative management models may include sand extraction at constant speed c in the form $\frac{dN^*}{dt} = aN^*\left(1 - \frac{N^*}{K^*}\right) - c$ or quota may be determined in proportion to the available quantity of sand: $\frac{dN^*}{dt} = aN^*\left(1 - \frac{N^*}{K^*}\right) - p \cdot x$, where p is a speed of sand extraction [23]. Alternative models require daily monitoring by GIS technology, while the Ferkhyulst model allows setting a quota based on available monitoring data using GIS.

If it becomes necessary to simulate the ecosystem or its individual components under variable in time external conditions, then the problem is reduced to the consideration of a non-autonomous system. At first, an autonomous system (model) is built and studied [1].

In accordance with the methodology for calculating damage [24], which is caused to the fish industry due to soil extraction, works, damage to the caviar, larvae and baby fish by hydraulic dredger is determined by the formula:

$$N = \Pi V R \frac{K}{100} M \; . \tag{4}$$

where N – amount of damages, Π – number of caviar, larvae and baby fish, V – volume of extracted soil, R – multiplicity of soil dilution with water, K – coefficient of industrial return from caviar, M – average weight of the adult fish.

If we need to determine the population size (caviar, larvae and baby fish), which is large enough, it is more convenient to use non-deterministic, but continuous models that have an independent variable of time. In the absence of other independent variables, it is described by ordinary differential equations.

Accepting that from equalities (3), (4), we get:

$$N = \frac{K^* N_0 e^{at}}{K^* + N_0\left(e^{at} - 1\right)} \cdot VR\frac{K}{100}M .$$

After separating independent of t values we get:

$$N(t) = K^* N_0 RM \frac{K}{100} \cdot \frac{V(t)e^{at}}{K^* + N_0\left(e^{at} - 1\right)} . \tag{5}$$

The resulting equation (5) is a dependence that describes an autonomous system.

One of the important properties of an autonomous system (model) is that it can have stationary solutions that determine the state of equilibrium of the real ecological system. It is necessary to find points that correspond to the state of equilibrium of the autonomous system (model). In the state of equilibrium, all the indicators of the ecosystem do not change over time, so in the stationary state, all derivatives of time in the system are zero, that is $\frac{dN}{dt} = 0$:

$$\frac{dN}{dt} = K^* N_0 RM \frac{K}{100} \cdot \frac{\left(\frac{dV}{dt}e^{at} + aVe^{at}\right)\left(K^* + N_0\left(e^{at} - 1\right)\right) - Ve^{at} \cdot N_0 a e^{at}}{\left(K^* + N_0\left(e^{at} - 1\right)\right)^2} .$$

As $\frac{dN}{dt} = 0$, $K^* + N_0\left(e^{at} - 1\right) \neq 0$, then

$$\left(\frac{dV}{dt}e^{at} + aVe^{at}\right)\left(K^* + N_0 e^{at} - N_0\right) - aVN_0 e^{2at} = 0 ;$$

$$\frac{dV}{dt}e^{at}\left(K^* + N_0 e^{at} - N_0\right) + K^* aVe^{at} + aVN_0 e^{2at} - N_0 aVe^{at} - aVN_0 e^{2at} = 0 ;$$

$$\frac{dV}{dt}e^{at}\left(K^* + N_0 e^{at} - N_0\right) + K^* aVe^{at} - N_0 aVe^{at} = 0 .$$

Taking into account $e^{at} \neq 0$ for $t \in R$, we get:

$$\left(K^* + N_0 e^{at} - N_0\right)\frac{dV}{dt} + \left(K^* a - N_0 a\right)V = 0 .$$

As a result of finding the derivative (5) and equating the result to zero, we obtain the differential equation $\frac{dV}{dt}$:

$$\left(K^* - N_0 + N_0 e^{at}\right)\frac{dV}{dt} = a\left(N_0 - K^*\right)V . \tag{6}$$

The equation (6) is integrated by the division of variables:

$$\frac{dV}{V} = a \cdot \frac{N_0 - K^*}{K^* - N_0 + N_0 e^{at}} dt , \ \ln V = a\left(N_0 - K^*\right)\int \frac{dt}{K^* - N_0 + N_0 e^{at}}$$

$$\ln V = a\left(N_0 - K^*\right)\left(\frac{t}{K^* - N_0} - \frac{1}{a\left(K^* - N_0\right)}\ln\left(K^* - N_0 + N_0 e^{at}\right)\right),$$

$$\ln V = -at + \ln\left(K^* - N_0 + N_0 e^{at}\right),$$

$$V = \left(K^* - N_0 + N_0 e^{at}\right)e^{-at}.$$

The solution of the equation, which determines the volume of extracted sand at the moment of time t, has the form:

$$V(t) = \frac{K^* + N_0\left(e^{at} - 1\right)}{e^{at}}. \tag{7}$$

4 GIS Based Approach and Quota Setting Experiment for Fish Population

4.1 GIS Based Approach

There is an acute need for regulation of production activities for the extraction of natural resources, calculation and allocation of quotas, depending on the ecological and economic situation of a particular area. Since 2016 in the Kherson region the solution of these problems requires conducting of hydrogeological survey, implementation of basin water management schemes, in particular in the Dniprovsky Basin Water Resources Management, substantiation of maximum allowable water and ecological loads, introduction of water management ecological-economic models. The data as a result of such works is extremely necessary for establishing regional quotas for extraction of natural resources while solving economic issues of southern Ukraine.

Representatives of local authorities and public organizations are concerned about the illegal sand extraction on the territory of the Kakhovka Reservoir. Thus, in the village Vesele, the Beryslav region, illegal sandwash and export of sand from the territory of the Kherson region are taking place (carts and barges go to Kamianske) as we can estimate from Google Map (fig.1).

Over the last decade or more, geographic information systems (GIS) have proved to be agile and powerful tools in academic and applied fields. The Google Maps mashup as Web application exhibits great potential to be a real live GIS. The power of GIS to analyze and illustrate suggested that public access to planning processes and research of many types would be greatly enhanced. Google Maps is a service which portends a subtle shift in GIS and what much of the world will be expecting of online geospatial business in coming years. Google Maps, the official Web service, is a quite simple tool very much similar to other online mapping services like MapQuest, Yahoo! Maps etc. This is a staple of Web-based GIS, and in Google Maps it is limited to only three choices: digital orthophotos, symbolized street maps, and a hybrid of the two [25].

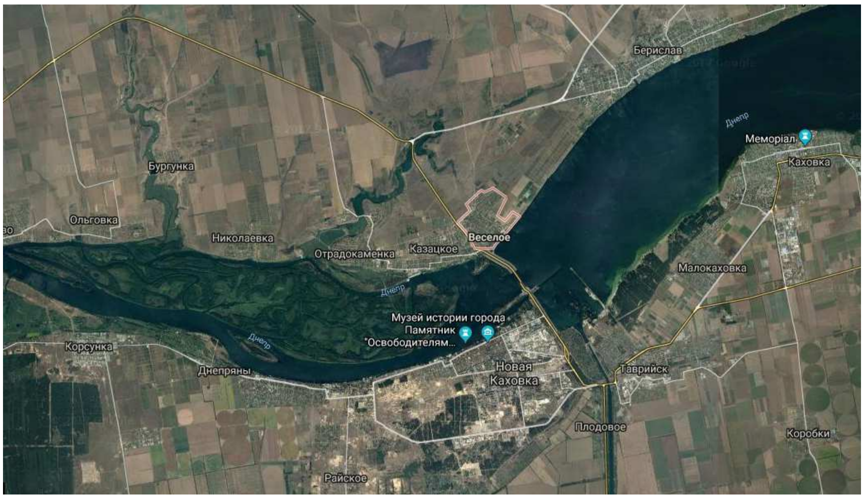

Fig. 1. Google Map based screenshot as GIS of sand extraction on the territory of the Kakhovka Reservoir

When one of results plotted on the map is clicked, a small scale is demonstrated in the bottom of this box. There is a unique and important additional component of Google Maps – its mashability. Google Maps mashups are the resultant combinations of the existing Google Maps geospatial query/display engine with geospatial data provided by non-Google users [25]. Google Maps lacks analytical power and accuracy, but it can be a platform for the addition of value by a participating public, a service to be mashed up, and the system to be possibly revised. It helps to build geospatial information resources that answer specific needs of specific industries.

It means creation of public participation geographic information system (PPGIS) that could support include necessary data to process information and make decisions of responsible persons. PPGIS applications have been extensive, ranging from community and neighborhood planning to environmental and natural resource management to mapping traditional ecological knowledge of people [26]. Example of Google Map application is demonstrated in table 1.

Table 1. Google Map applications

Year	Implementation mode	Location
2011	Google Maps	Otago Region (New Zealand)
2011	Google Maps	*Southland Region (*New Zealand*)*
2011	Google Maps	South West Victoria (Australia)
2010	Google Maps	Kangaroo Island (South Australia)
2010	Google Maps	Grand County (Colorado, U.S.)

In a recent Web-based PPGIS application authors provided an integrated Google Maps and Google Earth application interface that allowed participants the opportunity to examine and map any attribute in investigated area. We can distinguish 4 methods for collecting spatial information via PPGIS: 1) paper map and markers; 2) paper map and sticker dots; 3) flash-based Internet applications; 4) Google Maps/Earth Internet application [26]. Therefore we need to augment these applications with statistical data to make more a informative decision about resource extraction.

On the other hand authors [27] do not include popular web mapping Application Programming Interfaces (API's), such as Google Maps, Yahoo! Maps or BingMaps, Google Earth application on the list of free and open sources (fig. 2).

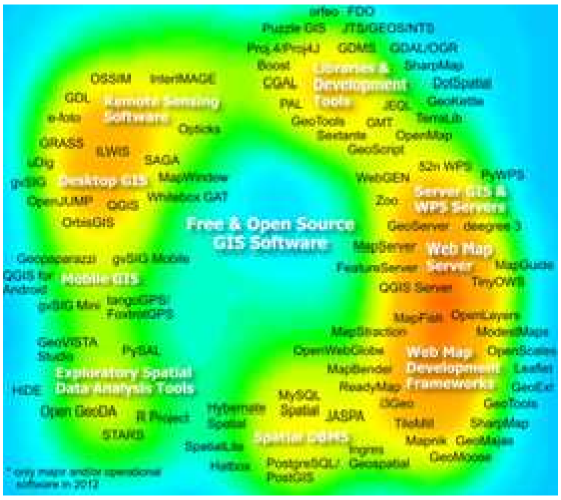

Fig. 2. Free and open source GIS Software

The reason is, that these maps are only free-of-charge in certain situations, and that their licence agreement imposes restrictions on users that limit the APIs uses to certain types of applications. For example these APIs are not free for commercial use, and private users are restricted in the daily frequency of use (number of map requests) of the services offered through these API. A recent example for a license change is the Google Maps API [27].

4.2 Quota Setting Experiment for Fish Population

Assume that a fish population at time t varies according to the following differential equation:

$$\frac{dN}{dt} = aN\left(1 - \frac{N}{K}\right) \tag{8}$$

where K – maximum capacity of fish in a water body, N – number of fish at time t, parameter $a > 0$. The solution of equation (8) is determined by the following logistic curve (fig. 3). The dynamics of the fish population is described by the logistic curve in fig. 3.

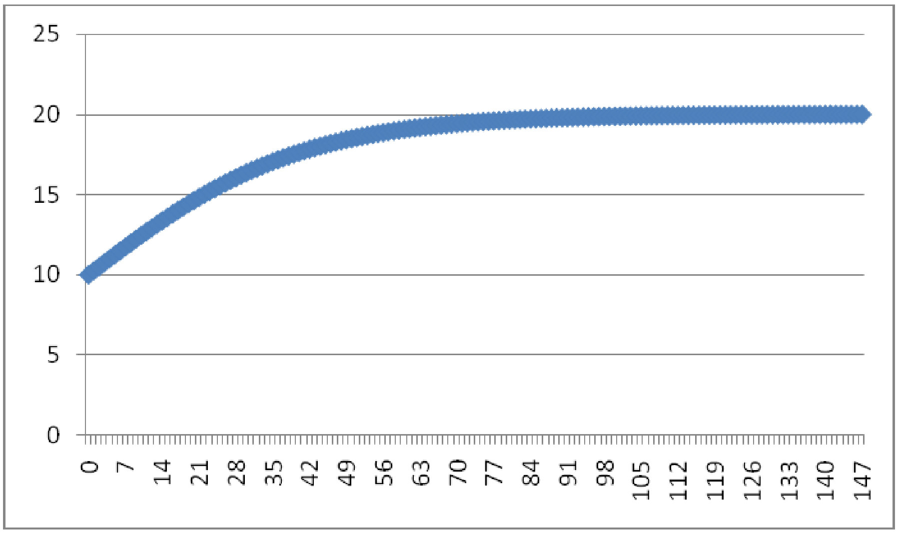

Fig. 3. The dynamics of the fish population (horizontal axis is time period in months, vertical axis is a number of fish population in tons)

In order to conduct a study, we need to choose the location of the site that is planned to be used for the sand extraction, taking into account the possible influence on the hydraulic structures that are below the current from the place of the sand extraction (Kakhovka HPS). The size of the production site, from which area sand is extracted, is determined by taking into account the relief of the water body and the coastal strip, the capacity of the sand deposits and the technical characteristics of the used equipment. Conditional unit of sand extraction taking into account the received values of quotas (20 tons), can be obtained from the area of 1 km^2 and, for example, corresponds to a strip along a coastline with a width of 0.05 km and a length of 20 km.

Let's set the following parameters for a water body, where sand is extracted from, for example, for building on the basis of quotas established by the regulatory authorities. The net growth rate of freshwater fish is 5% per year. The volume of water and sand are determined using GIS technology: the maximum sand capacity is $V = 1000$ tons, $\max K = 20$. The losses from the sand extraction in a water body are calculated by the formula:

$$N = N^* VR \frac{K}{100} M \tag{9}$$

Indices of equation (9) are explained in table 2.

For the initial values of the parameters, we will determine the social welfare SW, taking into account the profit of the business Π, which extracts sand from the water body and losses from loss of fish $c \cdot N$ (negative externality) due to the sand extraction. The volume of sand extraction is determined by the formula (7).

Table 2. Initial parameters for the calculation of losses from the sand extraction

Parameters	Explanation of the parameters	Units of measurement
N	amount of fish population's loss	Kg
N^*	number of fish in a population at time t	$\frac{animal\ unit}{m^3}$
V	volume of sand extraction	m^3
R	multiplicity of soil dilution with water	-
K	coefficient of industrial return from caviar	-
M	average weight of the adult	Kg

The dynamics of extracted sand volume V (m^3) for discrete time intervals (months) is shown in Table 3. The total revenue of the sand owner is calculated by the formula $TR = P \cdot V$ (P – price per 1 m^3). The profit of a firm that extracts sand is $\Pi = TR - TC$. The population of the fish at time t is determined from the formula (9) and is presented in table 3. Amount of fish population loss N is calculated by the formula (3), and the number of fish in the population N^* is computed by the formula (2) in table 3. In the monetary equivalent, the losses from damage done to fish (negative externality) due to sand extraction equal $c \cdot N$. Social welfare (net gain or loss of society) $SW = \Pi - c \cdot N$. Quota is $Q = \frac{V}{\max V}$.

Table 3. Dynamics of ecosystem's indicators due to sand extraction

t	V	TR	TC	Π	N^*	N	$c \cdot N$	SW	Quota
0	20	16800	12600	4200	10	70	3150	1050	2,0%
1	19,51	16390,33	12292,75	4097,58	10,25	70,00	3150	947,58	2,0%
2	19,05	16000,63	12000,48	4000,16	10,50	70,00	3150	850,16	1,9%
3	18,61	15629,95	11722,46	3907,49	10,75	70,00	3150	757,49	1,9%
4	18,19	15277,34	11458,00	3819,33	11,00	70,00	3150	669,33	1,8%
5	17,79	14941,93	11206,44	3735,48	11,24	70,00	3150	585,48	1,8%
6	17,41	14622,87	10967,15	3655,72	11,49	70,00	3150	505,72	1,7%
7	17,05	14319,38	10739,53	3579,84	11,73	70,00	3150	429,84	1,7%
8	16,70	14030,69	10523,02	3507,67	11,97	70,00	3150	357,67	1,7%
9	16,38	13756,08	10317,06	3439,02	12,21	70,00	3150	289,02	1,6%
10	16,07	13494,86	10121,14	3373,71	12,45	70,00	3150	223,71	1,6%
11	15,77	13246,38	9934,78	3311,59	12,68	70,00	3150	161,59	1,6%
12	15,49	13010,02	9757,51	3252,50	12,91	70,00	3150	102,50	1,5%

13	15,22	12785,18	9588,89	3196,30	13,14	70,00	3150	46,30	1,5%
14	14,97	12571,32	9428,49	3142,83	13,36	70,00	3150	-7,17	1,5%
15	14,72	12367,88	9275,91	3091,97	13,58	70,00	3150	-58,03	1,5%

The task of the regulator is to determine the quota at which social welfare will remain positive. In table 3 the quota size will be 1.5%. With a given quota size, the number of periods for granting a license on the sand extraction should be no more than 14 periods (months). The dynamics of social welfare is demonstrated in fig. 4, where during transition from 14 to 15 periods (initial first period is indicated as «0»), the increase in social welfare modifies from positive to negative meaning.

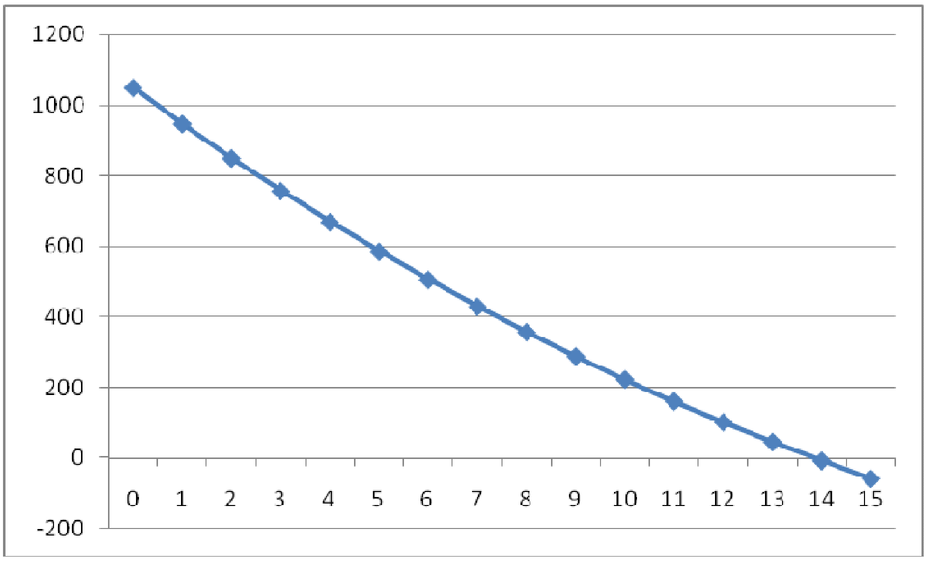

Fig. 4. Dynamics of social welfare due to sand extraction from water body (horizontal axis is time period in months, vertical axis is social welfare in monetary units)

5 Conclusions and Outlook

Instream mining can be conducted without creating adverse environmental impacts provided that the mining activities are kept within the limited optimal volume of sand mining set by the local authorities.

An example of mathematical model for determining of ecological equilibrium during sand extracting in the ecosystem is developed using Google Maps. The influence of economic activity due to sand extraction on fish fauna is described. The GIS based ecological-economic model is developed on the logistic model basis for establishing regional quotas for extraction of natural resources during economic activity in the southern Ukraine. Regulatory economic mechanism of natural environment is proposed. It implies such quota for sand extraction from water body, which does not lead to deterioration of the quality of the natural environment and stimulates the increase in social welfare.

We demonstrated that for chosen quota size, the number of periods for granting a license for the sand extraction should be no more than 14 periods (months) for our experiment in the Kherson region (Ukraine) using real data. The data of such works is extremely necessary for establishing regional quotas for extraction of natural resources in solving economic issues of southern Ukraine. This dynamic approach gives possibility to expand these results for local and national authority to determine quota size which saves exhaustible natural resources and increases social welfare for all participants using GIS based technologies.

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Method of the Multi-UAV Formation Flight Control

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Abstract. The main issue that arises when considering multi-UAV formation flight in a group is that of collision probability. In this case, without human control involved, it is artificial intelligence that is responsible for flight performance in the airspace in such a way that collision is avoided. Taking into account a rapid increase in civil and military applications of UAVs, a collision avoidance algorithm is proposed based on artificial potential field method. This method makes it possible to detect a potential conflict between multiple vehicles and other static or moving obstacles found in airspace, to provide collision resolution by changing UAVs flight parameters through maintaining minimum separation distance, including cases when manned vehicles are found in the same airspace. There can be distinguished a wide range of obstacles: static non-moving objects or vehicles having different sizes or flight parameters (multi-rotor, fixed wing and single rotor UAVs), or a few UAVs of one type but with different types of hardware configuration, at the same time considering the possibility of flight performance in the same airspace with manned aircraft. Group formation keeps shape on the flight path, taking into account some ground speed restrictions and turn bank angle values according to UAV's flight performance characteristics. The proposed method is used for multi-UAV control without any leader and provide multiple conflicts resolution, where each UAV is characterized by its protection zone.

Keywords: autonomous unmanned aerial vehicle, artificial potential field, synergetic, formation flight control.

1 Introduction

Remotely Piloted Aircraft System (RPAS) or Unmanned Aircraft System (UAS), colloquially known as 'drones', are aerial vehicles that fly without an on-board pilot, as well as the systems that support them to do so. RPAS refers to a system, extending beyond the Remotely Piloted Aircraft (RPA) or Unmanned Aerial Vehicle (UAV) to include ground stations (where control units and remote pilots are based) and communications infrastructures. Within the broad definition of UAS lies a diverse range of systems and UAVs. Some differences between these UAS are immediately apparent, such as the size or weight of UAVs. Other differences are more subtle, such as the medium of communication between the vehicle and the ground station. These systems have varying degrees of automation and autonomy, but usually include human remote pilots who control the vehicle from meters, kilometers or continents away. Perhaps the most established and visible applications of UAS are for military purposes, including combat and surveillance operations, but many applications have been identified for domestic uses such as environmental monitoring, security, emergency response, surveillance and recreation. In addition to the significant functional and economic benefits of these civil UAS, the technologies required for civil UAS operations are ready for market and the principal barriers to development in the sector are regulatory. In response to demand, the European Commission (EC) has published strategies to allow the gradual integration of UAS into normal airspace.

The main technical peculiarity of UAS is defined by the extent of autonomy and automation delegated from the pilot to the system. Automation levels range from those that are fully piloted from a remote location to those that are fully automated. There are also several points in-between, with some maneuvers triggered automatically through autonomous monitoring of conditions. Depending upon system priorities, autonomous maneuvers may have priority over, or be overridden by, the commands of a remote pilot. The International Civil Aviation Organization (ICAO) and current EC plans will only permit autonomous maneuvers to override pilot command in extraordinary circumstances such as communication failure or imminent collision risk. The UAS technologies beyond this definition, featuring greater autonomy, are also quite well developed and, while integration is not currently planned, it could plausibly follow a successful period of development in the UAS sector [1].

2 Analysis of Researches and Publications

The results of analysis show that most of known methods for multi-UAV control have a number of significant limitations that are connected with multiple conflicts resolution and group formation. Particularly, the main disadvantage that potential conflicts can be solved pairwise, when this issue needs to be done in a global way. For example, the system called Traffic Alert and Collision Avoidance System (TCAS) that is already installed aboard uses range measurements and range-rate estimates to determine if a conflict exists [2]. Methods developed for group control in robotics do not include such feature, so UAVs must deal with constant movement and limited turning ability, which makes collision avoidance much more complicated [3].

The classical approach is called geometric, in which aircraft trajectory predictions are based on linear projections of the current vehicle states [4-5]. The major disadvantage is that prediction errors are negligible only for short time periods and require high rate of surveillance information update. The class of stochastic approaches is related to the problem of probabilistic conflict detection in the presence of various uncertainties during the flight. The aircraft dynamics are described by using stochastic differential equations, and the future aircraft's trajectory is determined by solving the stochastic trajectory optimization problem, it could be applied for conflict definition at rather big distances [6], so stochastic approach can hardly be applied in order to control a group of UAVs flying close to each other.

Linear programming is a mathematical method [7] where optimal control problem lies in finding trajectories that minimize objective function. The drawback of such approach is the flyability of the optimal trajectories as far as safety and performance aspects of a given flight route are concerned.

The common disadvantage of all these methods is that they do not meet the main requirements with respect to autonomous UAVs: the absence of any communication links with the appropriate ground stations, with on-board computational and power sources being limited.

The summarized disadvantages of the analyzed methods make it impossible to simultaneously use a combination of such parameters as heading, speed and altitude change maneuvers to resolve multiple potential conflicts. Therefore, it is necessary to develop some new methods for multiple autonomous UAVs control in a group in a three-dimensional space. The method developed in this article is the evolution of potential field method proposed in article [8]. A potential fields approach is based on assigning magnetic or electrical charges of the same sign to UAVs, while the opposite charges are assigned to destinations, with the principle being based on the laws of physics according to which the like particles will repel each other, while the destinations having opposite charges will attract them. The main feature of such approach is that UAVs do not necessarily need to know the positions of all other aircraft, so artificial force generated by each UAV allows them to avoid each other spontaneously, at the same time keeping a group form [9]. According to [10], this approach is scalable and can be applied to a big number of UAVs, even in case of multiple conflicts.

3 Problem Statement

To solve this problem, a potential field approach is used. This method uses the property of the real world charged particles to generate a force field (electric or magnetic), which causes attraction and repulsion forces when these particles interact. The matter itself is a typical example of the self-organization principle in nature. UAVs are considered as dynamic objects with the same sign, with the point of destination having the opposite sign, it is analogous to the free movement of the aircraft autonomous motion where they constantly have potential conflicts, and it is required to avoid collisions with other dynamic objects or static/dynamic obstacles. In this case, the term 'potential conflict' is a situation, when the minimum separation standard between dynamic objects is violated. The protection zone of dynamic objects is generally defined as follows: the minimum allowed horizontal separation and the vertical separation requirement depending on the sizes of dynamic objects. The dynamic objects collision is the process of interaction between the dynamic objects or obstacles at a distance in which the dynamic objects change their direction of motion and the speed module.

The dynamic objects interact similarly to the particles of substances that are found in other aggregate states of matter (solid, liquid). The forces act simultaneously. For different dynamic objects, the general character of the force of gravity from distance is qualitatively the same: the force of attraction between dynamic objects dominates at large distances, while the force of repulsion acts at short distances. Fig.1 shows the qualitative dependence of interaction of forces between two dynamic objects found at distance r between two dynamic objects is presented, where F^+ and F^- – are the dependence of the attraction and repulsion forces respectively, and $F^+ + F^-$ - is a resultant force. At a critical distance $r = r_{cr}$ the resultant force is equal to zero, i.e. the forces of attraction and repulsion are counterbalanced. This distance r_{cr} corresponds to the equilibrium distance between the dynamic objects.

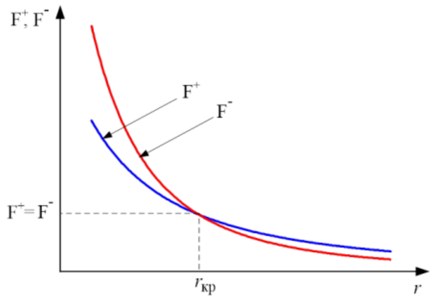

Fig. 1. The dependence of the attraction forces, the forces of repulsion between dynamic objects acting at a distance

This article considers a group system consisting of n autonomous UAVs, with a point-mass model used to describe UAV formation movement. The related variables are defined with respect to the inertial coordinate system and are shown in Fig. 2.

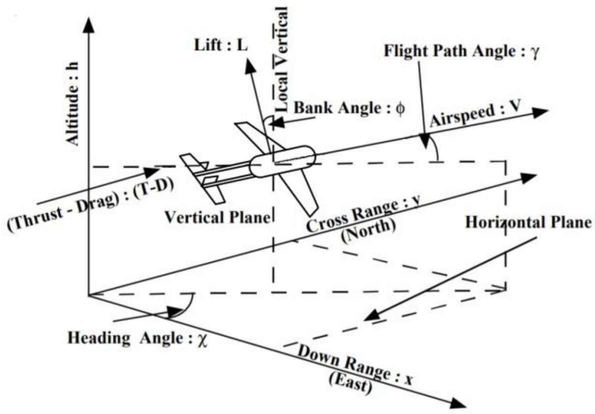

Fig. 2. UAV coordinate system

The point-mass UAV model captures most of the dynamical effects encountered in civil aviation aircraft. The point-mass equations of motion are formulated with respect to a coordinate system shown in Fig. 2. The point-mass model assumes that the UAV thrust is directed along the velocity vector, and that the UAV always performs coordinated maneuvers. It further assumes a flat, non-rotating earth. These assumptions are reasonable for UAVs operating within different ranges, therefore, this method can be used in conflict resolution between different types of UAVs, with the fidelity provided by the point-mass model being adequate for formulating these problems.

Point-mass models applicable for spherical earth approximations can also be developed. The fuel expenditure is negligible, i.e. the center of mass is time-invariant [11]. Under these assumptions, the motion equations of the i-th UAV can be described as follows:

$$
\begin{aligned}
\dot{x}_i &= V_i \cos\gamma_i \cos\chi_i\,; \\
\dot{y}_i &= V_i \cos\gamma_i \sin\chi_i\,; \\
\dot{h} &= V_i \sin\gamma_i\,; \\
\dot{\gamma} &= \frac{L_i \cos\varphi_i - g m_i \cos\gamma_i}{V_i m_i}; \\
\dot{\chi} &= \frac{L_i \sin\varphi_i}{m_i V_i \cos\gamma_i}; \\
\dot{V} &= \frac{T_i - D_i}{m_i} - g \sin\gamma_i\,;
\end{aligned}
\tag{1}
$$

where: i=1, 2, …, n is the index of multiple UAVs under consideration. x_i, y_i, h_i denote the components of UAV gravity center position. For i-th UAV, x_i is down range; y_i is cross range; h_i is altitude; V_i is ground speed; γ_i is flight path angle; χ_i is heading angle; T_i is engine thrust; D_i is drag; m_i is mass; g is acceleration due to gravity; φ_i is bank angle; L_i is vehicle lift. Bank angle φ_i and engine thrust T_i are control variables for an aircraft. Bank angle is commanded via combining rudder and aileron trims, thrust is commanded by engine throttle. The g-load $n_i=L_i/gm$ is controlled by elevator, though it refers only to UAV construction characteristics having higher limits due to the absence of crew on board an aircraft in comparison to traditional application. Throughout the multi-UAV control process, these control variables will be constrained to remain within their respective limits. The most common constraints considered are upper and lower bounds on ground speed (V_i), altitude (h_i), g-load (n_i), thrust (T_i), bank angle (φ_i) and climb or descent rates.

Heading angle χ_i and flight path angle γ_i are computed as:

$$\tan\chi_i = \frac{\dot{y}_i}{\dot{x}_i} \tag{2}$$

$$\tan\gamma_i = \frac{\dot{h}_i}{V_i} \tag{3}$$

In air traffic, conflict resolution is determined by separation constraints, forming the so-called conflict envelopes or ‘protection zones’ so that UAVs flight trajectories do not overlap during the flight. The conflict between two UAVs or an UAV with the above-mentioned obstacles implies that their altitude should differ in value h_{pr} given in UAV flight performance characteristics, or they should not get closer in the horizontal plane than indicated by value r_{pr}. The protection zone can be visualized for each UAV as shown in Fig. 3.

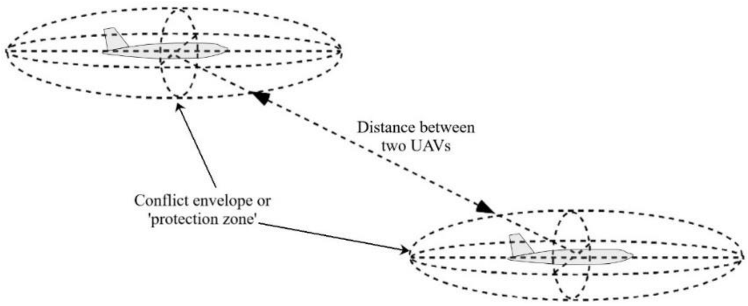

Fig. 3. Spheroidal conflict envelope or 'protection zone' and distance between two UAVs in the vertical plane

4 Method of the Multi-UAV Formation Flight Control

In order to apply this approach it is required to transfer the real world properties of UAVs and their position coordinates to the virtual world with its synergetic properties, with the potential conflicts that may occur on the flight path being taken into account. [12-13].

This process includes the following steps:

- structural and parametric synthesis of the virtual world;
- structure formation and parameters of virtual measuring systems that provide conflict free trajectories calculation.

UAVs are transferred from real to virtual world as dynamic objects, with mass, attraction and repulsion potentials values being assigned to them. So, the equilibrium state can be represented as:

$$F^{+}(m_i, m_j, G, r_{cr}^{\alpha}) = F^{-}(m_i, m_j, G, r_{cr}^{\beta}) \tag{4}$$

where m_i, m_j – masses of i-th and j-th dynamic bodies, G – gravitational constant,

Attraction and repulsion forces can be calculated as:

$$F_{ij}^{+} = \frac{G m_i m_j}{r_{ij}^{\alpha}}; \qquad \alpha \in \{2, 3, \dots\}; \tag{5}$$

$$F_{ij}^{-} = \frac{G m_i m_j r_{\text{кр}}}{r_{ij}^{\beta}}; \qquad \beta \in \{3, 4, \dots\}; \tag{6}$$

Projections of attraction and repulsion forces between i-th and j-th bodies on axes X and Y are calculated by the formulas:

$$F_{ijx}^{+} = F_{ij}^{+} \frac{|x_i - x_j|}{r_{ij}} \qquad F_{ijx}^{-} = F_{ij}^{-} \frac{|x_i - x_j|}{r_{ij}} \tag{7}$$

$$F_{ijy}^{+} = F_{ij}^{+} \frac{|y_i - y_j|}{r_{ij}} \qquad F_{ijy}^{-} = F_{ij}^{-} \frac{|y_i - y_j|}{r_{ij}} \tag{8}$$

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{9}$$

In equations (5) and (6), the aggregate state of the environment of the virtual world (solid, liquid, gas) is chosen by the ratio *α/β*, which characterizes the degree of self-organization of the dynamic objects. Analogy of the aggregate state of a virtual environment can serve as an aggregate state of matter - gaseous, liquid, crystalline, etc.

The resultant vector at each point of dynamic object location consists of the sum of attraction and repulsion forces $F_{ij}^{+} + F_{ij}^{-}$, but can perform a group formation, so to produce dynamic objects movement there should be present one more force which takes into account thrust force P_{ijx}, P_{ijy} direction with projection on axes *X* and *Y* (Fig. 4):

$$\mathrm{F_{ijx}} = \mathrm{F_{ijx}^{+}} + \mathrm{F_{ijx}^{-}} + P_{ijx} \tag{10}$$

$$\mathrm{F_{ijy}} = \mathrm{F_{ijy}^{+}} + \mathrm{F_{ijy}^{-}} + P_{ijy} \tag{11}$$

$$\mathrm{F_{ij}} = \mathrm{F_{ij}^{+}} + \mathrm{F_{ij}^{-}} + P_i(\chi_i) \tag{12}$$

The main condition for dynamic object motion should be satisfied in the following way: $F_{ij}^{+} + F_{ij}^{-} < P(\chi_i)$. The group consists of *n* dynamic objects and each of them can be described by the system of equations:

$$\frac{d^2x_i}{dt^2} = \frac{1}{m_i}\sum_{i\neq j}^{n}(\mathrm{F_{ijx}^{+}} - \mathrm{F_{ijx}^{-}} + P_{ijx}) \tag{13}$$

$$\frac{d^2y_i}{dt^2} = \frac{1}{m_i}\sum_{i\neq j}^{n}(\mathrm{F_{ijy}^{+}} - \mathrm{F_{ijy}^{-}} + P_{ijy}) \tag{14}$$

$$i \in n, j \in n.$$

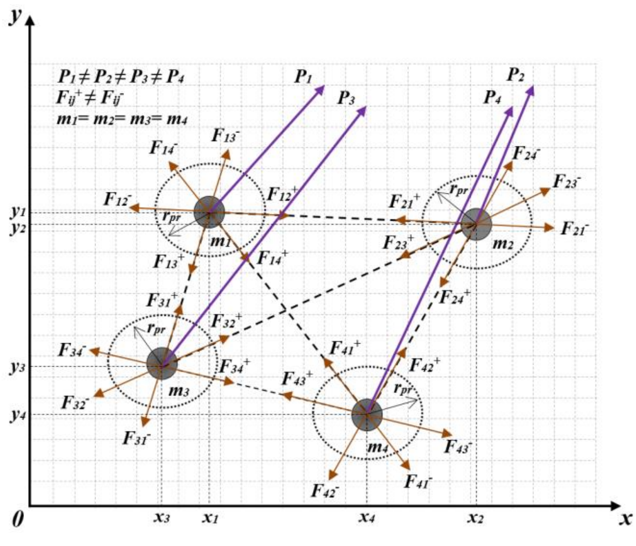

Fig. 4. The scheme of forces with four dynamic objects in the original position

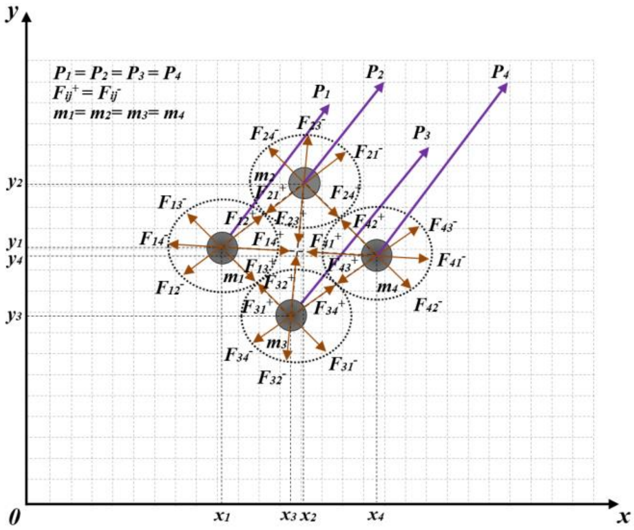

Fig. 5. The scheme of forces with four dynamic objects after group formation

The main advantage of the virtual world that was formed is that when the dynamic objects approach the critical distance r_{pr}, the resultant force acting on them is zero, i.e. the forces of attraction and repulsion balance each other. Thus, r_{pr} allows to set the size of the dynamic objects protection zone.

$$\mathrm{F}_{\mathrm{ij}}^{+} = \mathrm{F}_{\mathrm{ij}}^{-} \tag{15}$$

The absence of intersections of such zones, taking into account the uncertainty of the forecasted position of the dynamic objects, allows maintaining a guaranteed level of traffic safety in the multi-UAV formation flight control (Fig. 5).

If a static obstacle occurs on a multi-UAV path, the group interacts with it through applying attraction F_O^+ and repulsion F_O^- forces (Fig. 6). This type of maneuver can be conducted provided F_O^- is neglected, because the obstacle is static:

$$F_O^+ < \mathrm{F}_{\mathrm{ij}}^{+} + \mathrm{F}_{\mathrm{ij}}^{-} + P_i(\chi_i) \tag{16}$$

The values of heading angle χ_i and ground speed V_i may change depending on dynamic objects location relative to the obstacle and destination point.

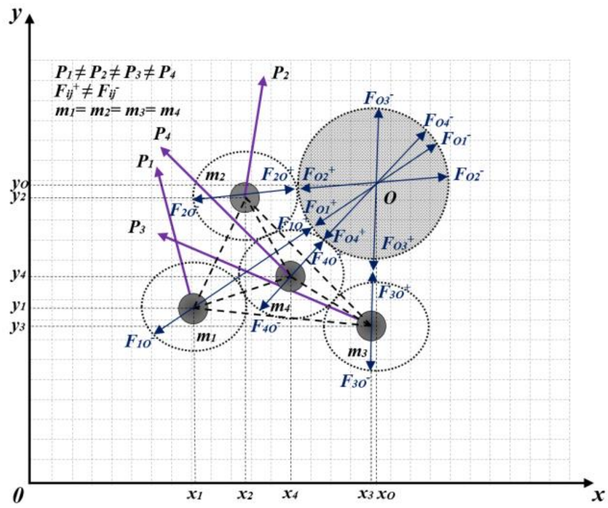

Fig. 6. The scheme of forces with four dynamic objects in a group avoiding an obstacle

5 The Multi-UAV Formation Flight Control Simulation

In order to find out if the potential field approach can be applied in the solution of the problem of multi-UAV formation flight control, Matlab simulators were used. All in all, 2 cases were simulated with a different number of dynamic objects, with UAV being referred to as a dynamic object. In Experiment 1 (see Fig. 7), 8 dynamic objects were considered with the point-mass of 1 kg and protection radius 3 m, with only one 6 m-radius obstacle to overcome. In Experiment 2 (see Fig. 8), 12 dynamic objects were considered whose point-mass was 1 kg and protection radius was 3 m, with three obstacles in the way whose radii varied from 3.5 to 4.5 m. The path was divided into 3 main stages of flight: 1) group formation; 2) obstacle avoidance; 3) straight line flight in a group to the destination. Figures represent dynamic objects movement trajectory (a), distance between moving dynamic objects, with dotted line showing protection zone with radius 3 m (b), heading angle χ_i (c) and change in ground speed V_i (d).

$$\tan \chi_i = \frac{\dot{y}_i}{\dot{x}_i} \text{ or } \tan \chi_i = \frac{\mathrm{F_{ijy}}}{\mathrm{F_{ijx}}} \tag{17}$$

$$V_i = \sqrt{\dot{x}_i + \dot{y}_i} \tag{18}$$

The dynamic objects are in their original positions with the starting speed being equal to zero. At the first stage of modelling, due to the action of attraction (5) and repulsion (6) forces the process of group formation begins, which depends on the distance between them (9). Heading angle χ_i has the same direction as vector F_{ij}, which is projected on axes X (10), Y (11) and is formed by their sum, including thrust force (12). At the same time, the shape of group formation is regulated be the equilibrium state (4), (15).

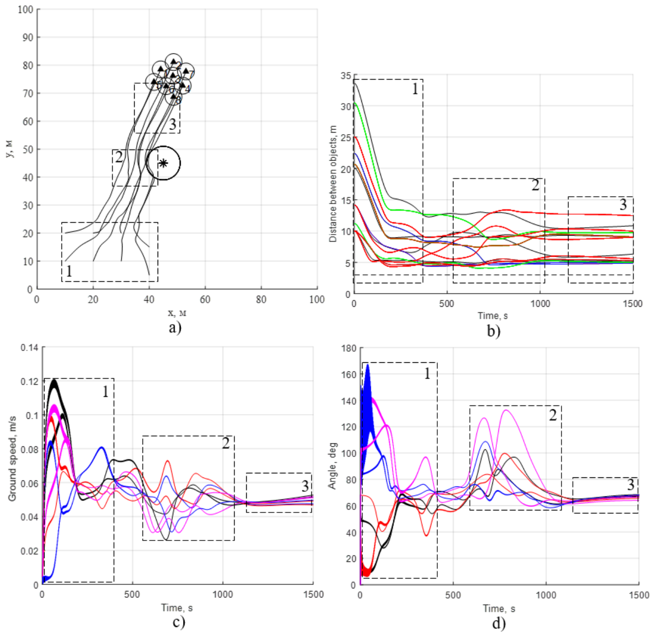

Fig. 7. Experiment 1: a) trajectory of movement; b) distance between objects; c) ground speed; d) heading angles

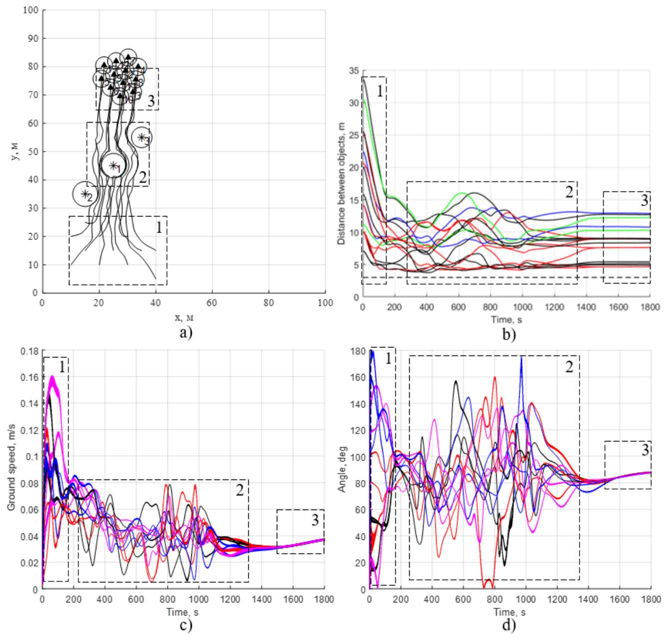

Fig. 8. Experiment 1: a) the trajectory of movement; b) the distance between objects; c) ground speed; d) heading angles

6 Conclusions

1. UAVs are widely used in different areas of human activity, and multi-UAV performance has many advantages compared with the performance of an individual UAV. Research institutions and groups are currently developing an algorithm for a group of UAV autonomous control since manual control is not available.

2. For multi-UAV formation control, the artificial potential field approach is used, where UAVs are denoted as interacting dynamic objects influenced by attraction and repulsion forces. The movement of each dynamic object is described by a system of equations, with the direction of movement coinciding with thrust force angle projected on each of axes.

3. To check the potential field approach applicability, two simulations were performed for 8 and 12 dynamic objects. The tasks were to form a group, avoid obstacles, and continue movement in the given direction with no change in the shape of the group. The results show that in this form the approach can be applied to a group formation and multi-UAV flight control. All dynamic objects moved within the allowable range determined by heading angle χ_i and ground speed V_i keeping within protection zones.

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Collecting the Seminal Scientific Abstracts with Topic Modelling, Snowball Sampling and Citation Analysis

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Abstract. This paper presents a complete information technology for collecting and analysis of a citation network of scientific publications aimed at detecting of seminal papers in a selected domain of research. The technology consists of the seed paper selection, plain snowball sampling, probabilistic topic modeling, greedy restricted snowball sampling, and analysis of the collected citation network.

The topic model is built on the base of word-word co-occurrence probability with combination of sparse symmetric nonnegative matrix factorization and principal component approximation. Experiments with the collection of High Energy Physics abstracts show that the number of topics in the model is determined in natural way and the Kullback-Leibler divergence correlates with cosine similarity calculated from keywords provided by publication authors.

The citation networks on "critical thinking" and "automatic pronunciation assessment" domains are collected and analyzed. The analysis shows that both networks are "small worlds" and therefore the observed saturation of the restricted snowball sampling can provide the complete set of publications in domains of interest. Multiple runs of the sampling confirm the hypothesis that the set of seminal publications is stable with respect to variations of the seed papers. The modified main path analysis allows to distinguish the seminal papers including new publications following main stream of research.

Keywords: text mining, short text document, topic modelling, principal component analysis, sparse symmetric nonnegative matrix factorization, citation network, main path analysis.

1 Introduction

The quality of a related work review is a problem well known to each scientist. The questions to be answered are "If the collected scientific publications contain all notable scientific results of the domain of interest?" and "Which of the collected publications direct the mainstream of the knowledge evolution in the domain of interest?" Below we present a complete information technology for getting answers to both questions. The essence of the technology is the collecting and analysis of a citation network of scientific publications aimed at detecting of seminal papers in a selected domain of research.

To our best knowledge, while the separate parts of the method are developed, the entire procedure that takes the small set of papers on some scientific domain and produces perfect list of references is not known.

The objectives of the presented work are:

- to present the complete technology that takes a manually selected seed papers and produces the short list of interconnected scientific publications that reflects evolution of main ideas of the selected scientific domain. The technology contains both restricted snowball sampling method and citation network analysis.
- to test all initial assumptions, namely
  - if the proposed snowball restriction method [6] provides adequate semantic distance between publications;
  - if the obtained restricted snowball forms the scale-free network [22];
  - if the restricted snowball provides saturation of the publication dataset;
  - if the best age of the seed papers is 5–10 years;
  - if the biased seed papers can produce unbiased citation network.

The distinctive features of the presented method are application of the probabilistic topic model to perform restricted snowball sampling and collect citation network, then the main path analysis is applied to point both the most influential publications and the main path of scientific knowledge evolution. The main path allows detecting the newest publications that follow the mainstream and the outliers that potentially contain the completely new ideas.

The structure of the paper is following. Section 2 overviews the publications related to the presented technology, Section 3 contains description of the crucial steps of the algorithm, Section 4 states the experiment pre-conditions and Section 5 discusses the results. Conclusion summarises the main results and discusses future work.

2 Related Work

Publications on a domain of knowledge can be collected from conference proceedings [7], the study of the co-authorship [15, 16], elaboration of keywords and topics [14, 17], querying academic search engines[1] with a set of keywords or snowball sampling [10, 1, 6]. However, not for every research domain there is a corresponding conference, as well as one author can write papers on different topics. Building maps and ontologies of large scientific domains does not provide the list of references rather the set of interconnected concepts. Querying with

[1] Google Scholar, https://scholar.google.com,
Semantic Scholar, https://www.semanticscholar.org/,
Microsoft Academic, https://academic.microsoft.com/

a set of keywords produces the biased set of publications [19] because different researchers use slightly different terms to report their results.

The most appropriate way to collect scientific papers is snowball sampling [10, 1], when each publication from the current queue is considered then all referenced papers and all papers referencing to the publication are added to the next level queue. The snowball sampling allows collecting publications on the narrow research topic and connect them in the citation network [22]. The high quality of citation-based search algorithm is provided with phenomena of "small world" which is a proved property of scale-free networks [2, 22]. Newman [15] has shown that in the most of the cases it is enough to do three iterations. However, the statistical properties of global citation network including all scientific papers is not known, that is why we need to test if the small world assumption is true for the collected subset of citation network and if the three iterations allows collecting most of the papers.

Another point of snowball sampling is dependence on the initial queue called a seed collection. The general advice [10] recommends that the seed papers should be the seminal papers of the knowledge domain pointed by experts or the papers selected by the researcher. Valid seed papers should be 5–10 years old and have to be widely cited. The best seeds are the reviews, foundational or framing articles on the topic of interest. However, the advice also should be checked. Moreover, we need to test if the biased seed papers can produce unbiased citation network.

The snowball sampling cannot be applied directly to publication crawling because the list of references can contain the items that are not directly related to the investigated domain. Therefore the straightforward implementation of snowball publication sampling causes infinite collection inflation and some restrictions should be introduced to accept or reject the candidate publication. It should be noted that the introduced restrictions can violate the small world property and we need to check if the restricted snowball result is scale-free citation network.

To filter out the most relevant papers while sampling Ahad et al. [1] in their approach use vector document model and cosine similarity, however the document vector model relies on word spelling rather than meaning that causes precision loss when the short texts are considered. Lecy et al. [10] apply PageRank calculated by Google Scholar as a measure of paper significance. However, PageRank is a property of a global citation network including all topics of knowledge, so it cannot be calculated from its small subset. One of the most promising approaches is the probabilistic topic model (PTM).

Probabilistic topic models [24] use a large collection of documents and statistical approach to model words and documents as vectors in a high-dimensional semantic space R^n, where n is much less than number of words and number of documents. The base idea of PTM is to construct few topis which are groups of tightly connected words. Then document words are represented as a result of two-stage random sampling. The most known method of topic modelling is Latent Dirichlet Allocations (LDA) [5] which is successful and simple enough.

A general introduction and survey of the topic modelling can be found in [24] along with a novel approach, called Additive Regularization of Topic Models.

However, in most of the scientific databases, full texts are often protected by copyright. Therefore the only information we can use are paper title, paper abstract, and sometimes the database-specific keywords and topics. So the documents that we analyse are short and common PTMs based on document-word statistics lose their precision. This shortcoming is overpassed with approaches utilizing word co-occurrence statistics in Biterm Topic Model (BTM) [25] and Word Network Topic Model (WNTM) [26] instead of counting document-word pairs. Another method of word embedding, called GloVe, is proposed in [18]. It is based on word-word co-occurrence matrix and uses global matrix factorization, so it is close to BTM [25] and WNTM [26] statistical topic modelling.

Also, the vague part of common PTMs is that number of topics cannot be determined with document analysis. To overcome this weakness, handling the word-word co-occurences with principal component analysis (PCA) and sparse symmetric nonnegative matrix factorization (Sparse SNMF) was proposed [6].

The collected citation network [22] can be analyzed using citation count and other simple statistics [12], PageRank [11], information retrieval techniques [1], knowledge graph [17], combined supervised machine learning approaches [23] or Main Path analysis [12].

The most appropriate way to highlight the seminal papers of the small scientific domain is main path analysis because the method deals only with the collected citation network and allows to increase the precision of sampled dataset. On the contrary, the citation count and other statistics, supervised machine learning applied by Valenzuela, Ha and Etzioni [23] and PageRank cannot point out the tightly interconnected subset of the citation network. Klink-2 [17] and similar algorithms aim to build the map of knowledge domain but do not seek the most influenced publications.

3 Information Technology Overview

The general workflow of the restricted snowball sampling is introduced in [6]. It contains the following steps:

1. Collect a set of seed papers and put them in the initial, 0-th, queue.
2. Run several iterations of the unrestricted snowball sampling to pickup baseline documents. For $n \in 0, 1, 2, 3$
   1 get a portion of papers from the n-th queue;
   2 download the papers referenced by the portion;
   3 download the papers referencing the portion;
   4 add all the downloaded papers to the $(n+1)$-th queue.
3. Create the PTM using baseline documents:
   1 extract title and abstract from each document of the collection;
   2 split all the titles and abstracts into sentences;
   3 create the dictionary containing all the nouns and adjectives that occur in the sentences;

4 combine all terms from the reduced dictionary occurring in the same sentence into pairs and build the joint probability matrix;
5 detect the collection specific stop-words and exclude them from the reduced dictionary;
6 perform Sparse SNMF to create PTM;
7 map each of the seed papers to a vector of topic probabilities.

4. Perform the batch restricted snowball sampling: for $n \in 0, 1, 2, 3$
   1 get a portion of papers from the n-th queue;
   2 download the papers referenced by the portion;
   3 download the papers referencing the portion;
   4 extract bag of stemmed words from each of downloaded papers;
   5 map each of the downloaded papers to a vector of topic probabilities;
   6 calculate distance from each downloaded paper to the seed papers;
   7 add to the next level queue only those of downloaded papers which are close to the seed papers.
5. Analyse the citation network.

The details of the restricted snowball sampling and probabilistic topic model construction are discussed in [6].

4 Citation Network Analysis

4.1 Cycles Elimination

The correctly built citation network must be an acyclic directed graph. However, the publication database errors accidentally can cause cycles. The problem with cycles is that if there is a cycle in a network then there is also an infinite number of paths between some vertices. Since a citation network is usually almost acyclic to transform it into an acyclic network we use the "preprint" transformation described by Batagelj [3]. First, we identify cycles and then each paper from a cycle is duplicated with its "preprint" version and the papers inside cycle cite "preprints".

4.2 Simple Citation Path Count

Our approach is similar to Search Path Count (SPC) algorithm [12, 3]. We introduce two pseudo-vertices – source and target. A vertex that does not reference any other publication vertex, gets an edge to the target vertex. A vertex that is not referenced by any publication vertex, gets an edge from the source vertex, so the graph becomes connected. Next step is to calculate all simple paths from the source to the target using Python library NetworkX[2]. The algorithm uses a modified depth-first search to generate the paths [9]. As the result we obtain a set of paths, each of which is a sequence of vertices. Each pair of direct neighbour vertices in such a sequence is an edge in the citation graph. For each edge, its

[2] NetworkX, https://networkx.github.io

frequency is calculated against all paths – a number of paths through it, simple path count. Next we calculate edge resistance as inverse proportional to edge simple path count – this allows diminishing the difference among the most cited and least cited papers [21, 8]. The path resistance is then calculated as the sum of its edge resistances. Finally, we set an order over the paths using the path resistances. Using path resistances is a distinguishing feature of the proposed algorithm.

The difference of the applied algorithm from SPC algorithm is the preservation of the citation graph connectivity. In the known algorithm [4], as soon as the edge SPC scores are calculated the edges having low scores are removed and the citation network can become a disconnected graph.

4.3 Chasing New Ideas in Publications

Path resistance allows detecting new publications in the field, not referenced yet by any other authors but existing in a mainstream of the domain. We can separate all papers into mainstream research and probably new research fields or directions. The smallest (up to a certain threshold) path resistances correspond to the mainstream, whereas the biggest path resistances correspond to the publications that are either brand new, bad written or published in a low impact journal/conference proceedings. We assume those publications are the source of potentially new ideas and topics.

5 Analysis of Experimental Results

5.1 Experimental Settings

We took three different corpora: "high energy physics"(HEP), "critical thinking"(CT) and "pronunciation quality assessment"(PQA).

HEP publications [20] are available from the European Laboratory for Nuclear Research. The hep-ex partition of the HEP collection is composed of 2802 abstracts related to experimental high-energy physics that are indexed with 1093 main keywords (the categories), the hep-astroph partition contains 2716 abstracts from astrophysics section and 18114 abstracts on theoretical physics in hep-th metadata. Each publication is manually annotated with keywords.

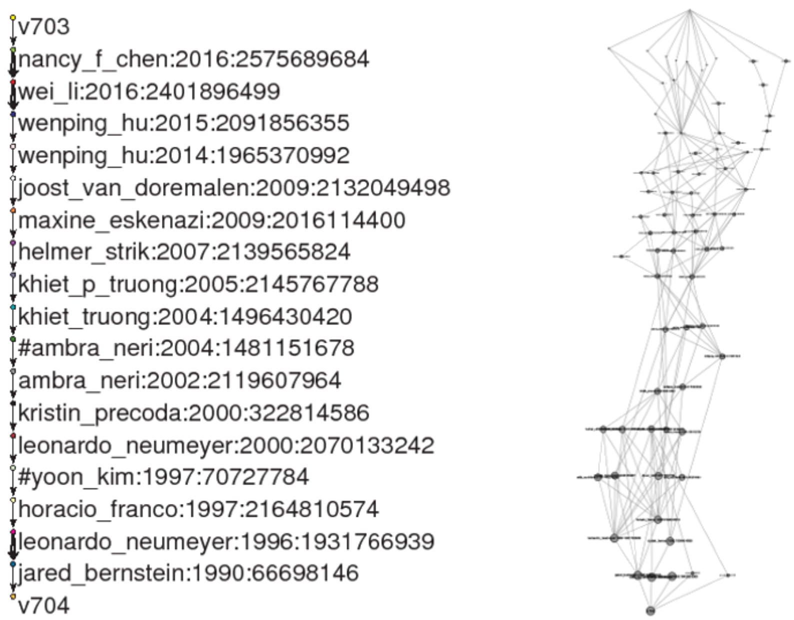
CT corpus is gathered with our snowball sampling software. The CT domain is characterized with a large noisy publications corpus tightly entangled with publications on psychology, didactics, pedagogy and phylosophy. The size of CT corpus is 24040 publication abstracts.

PQA domain is very specific and narrow, with a moderate-size corpus containing 8339 scientific abstracts collected by our snowball sampling software.

The sampling was run with following parameters: percentage of stop words to exclude – 2%; percentage of rare words to exclude – 5%; number of components in PCA which is maximal number of topics – 200; threshold KL-divergence – 0.18; sparsity parameter – 0.05; number of top citation paths – 50; minimal number of citations – 3.

5.2 Seminal Publications for PQA domain

Figure 1 shows the results of citation network analysis for PQA domain.



a b

Fig. 1. Top path in PQA citation network (a) and top 73 paths of the citation network (b). Nodes are marked as (first author:year:MS_Academic_Id)

On the part (a) of Figure 1 we can see that the mainstream of pronunciation assessment contains the publications:

1. "Automatic evaluation and training in English pronunciation" by Bernstein, Cohen, Murveit, Rtischev, and Weintraub, 1990
2. "Automatic text-independent pronunciation scoring of foreign language student speech" by Neumeyer, Franco, Weintraub, and Price, 1996
3. "Automatic pronunciation scoring for language instruction" by Franco, Neumeyer, Kim, and Ronen, 1997
4. "Automatic pronunciation scoring of specific phone segments for language instruction" by Kim, Franco, and Neumeyer, 1997
5. "Automatic scoring of pronunciation quality" by Neumeyer, Franco, Digalakis, and Weintraub, 2000
6. "Effects of speech recognition-based pronunciation feedback on second-language pronunciation ability" by Precoda, Halverson, and Franco, 2000

7. "The pedagogy-technology interface in computer assisted pronunciation training" by Neri, Cucchiarini, Strik, and Boves, 2002
8. "Segmental errors in Dutch as a second language: how to establish priorities for CAPT" by Neri, Cucchiarini, and Strik, 2004
9. "Automatic pronunciation error detection in Dutch as a second language: an acoustic-phonetic approach" by Truong, 2004
10. "Automatic detection of frequent pronunciation errors made by L2-learners" by Truong, Neri, Wet, Cucchiarini, and Strik, 2005
11. "Comparing classifiers for pronunciation error detection" by Strik, Truong, Wet, and Cucchiarini, 2007
12. "An overview of spoken language technology for education" by Eskenazi, 2009
13. "Automatic detection of vowel pronunciation errors using multiple information sources" by Van Doremalen, Cucchiarini, and Strik, 2009
14. "A new neural network based logistic regression classifier for improving mispronunciation detection of L2 language learners" by Hu, Qian, and Soong, 2014
15. "Improved mispronunciation detection with deep neural network trained acoustic models and transfer learning based logistic regression classifiers" by Hu, Qian, Soong, and Wang, 2015
16. "Improving non-native mispronunciation detection and enriching diagnostic feedback with DNN-based speech attribute modeling" by Li, Siniscalchi, Chen, and Lee, 2016
17. "Computer-assisted pronunciation training: From pronunciation scoring towards spoken language learning" by Chen and Li, 2016

The mainstream evolution of pronunciation assessment starts from application of automatic speech recognition, pays some attention to pedagogical aspects, goes to simple machine learning approaches, then to neural networks and to deep learning. Some of the seminal publications are the reviews containing discussions of the feature selection, methods comparison and combination. The part (b) of Figure 1 shows that the more top paths we keep, the more detailed knowledge map we obtain.

5.3 Assumptions Checking

PTM as a restriction criteria for the proposed restricted snowball sampling method provides adequate semantic distance between publications. To check the statement we took HEP collection, built PTM for it, and measure similarity using keywords annotating each publication from HEP collection. For each pair of HEP publications were calculated both symmetric KL-divergence and cosine similarity. The results are shown in Figure 2.

As we can see, the PTM-based symmetric Kullback-Leibler divergence [13] provides reliable upper bound for the keyword based cosine similarity. The reason is that the cosine similarity uses only word spelling and PTM uses R^n word embedding taking into account the meaning of terms.

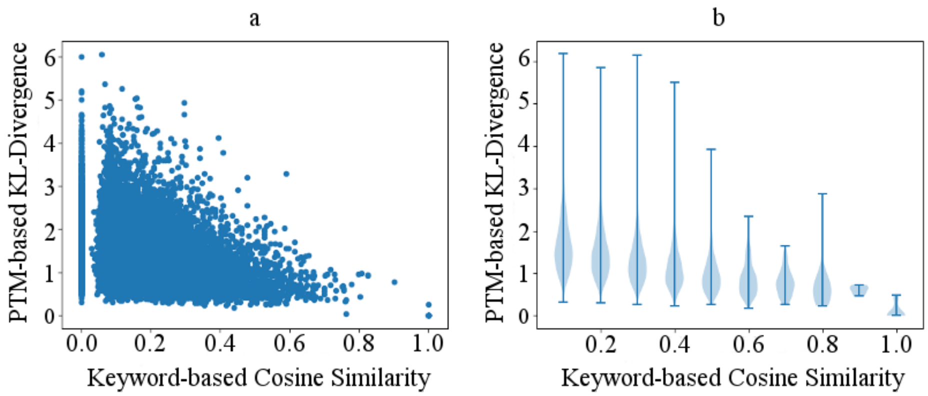


Fig. 2. Symmetric PTM-based KL-divergence and cosine similarity for the HEP abstracts: (a) scatter plot; (b) violin plot.

The restricted snowball sampling forms the scale-free network. Derek de Solla Price showed in 1965 [22] that the number of references to a paper (node degree) in a citation network had a heavy-tailed distribution following the power law and thus that the citation network is scale-free. One of our initial assumptions was that the restricted snowball sampling results in a scale-free networks so we need a few number of snowball iterations to achieve the high recall. Figure 3 was calculated on the base of PQA corpus and shows that for the small node degrees the logarithm of node number has linear dependency on the logarithm of node degree and for the large node degrees the dependency has heavy tail. That means, the restricted snowball sampling produces scale-free citation network as well as classical snowball. So we can be sure that a few iterations of the restricted snowball sampling allow collecting most of the relevant publications.

Saturation of the restricted snowball sampling. The restricted snowball sampling can be modelled as Poisson process when the publications appear sequentially and we can either (a) accept n-th publication and add it to the snowball or (b) don't accept. So we can calculate the confidence interval of Poisson distribution of event (a) and compare its upper bound with some pre-defined acceptance probability. Figure 4 shows 0.95 confidence interval of Poisson distribution of paper acceptance as a colored strip and acceptance probability threshold 0.05 as a straight line. The confidence interval was calculated on the base of 10 snowball runs for CT collection starting from random subsets of seed paper collection. After some number of tested abstracts the upper bound of confidence interval becomes lower than the threshold so the restricted snowball sampling guarantees the saturation.

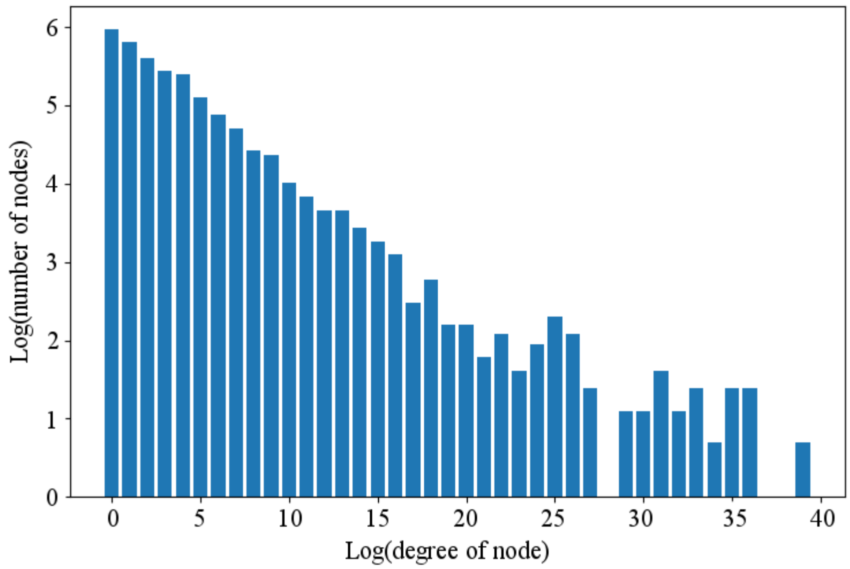


Fig. 3. Citation network node degree distribution in log-log scale.

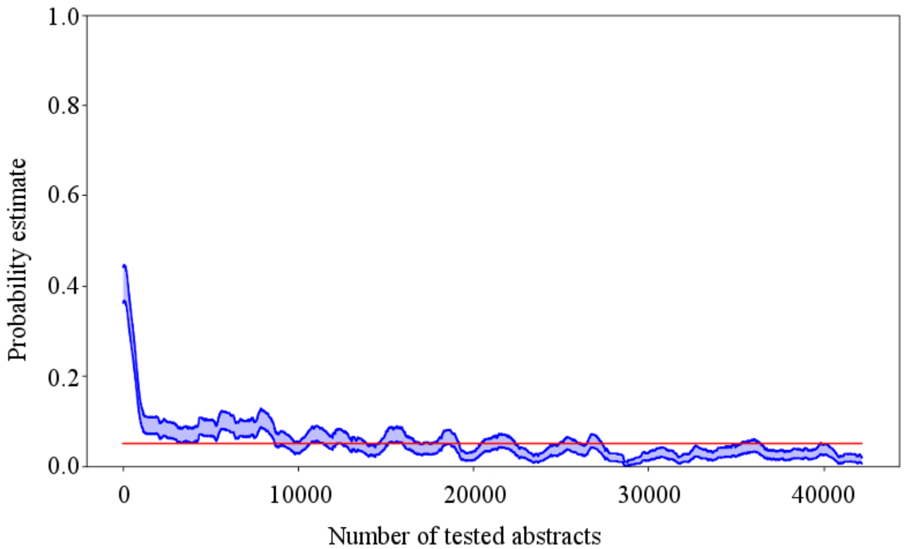


Fig. 4. 0.95 confidence interval of Poisson distribution of paper acceptance as a function of the number of already tested abstracts N and acceptance probability threshold 0.05.

The Citations Age To study the influence of a publication age on the probability of the publication citation we have attributed each edge of the PQA citation network with age calculated as difference between years of referencing publication and referenced one. The number of the edges as a function of edge age is shown on Figure 5. We can see that the maximal number of the references is observed for the publications that are 2–8 years old. Such publications are still regarded as new ones but at the same time are old enough to be read and estimated by many reserchers.

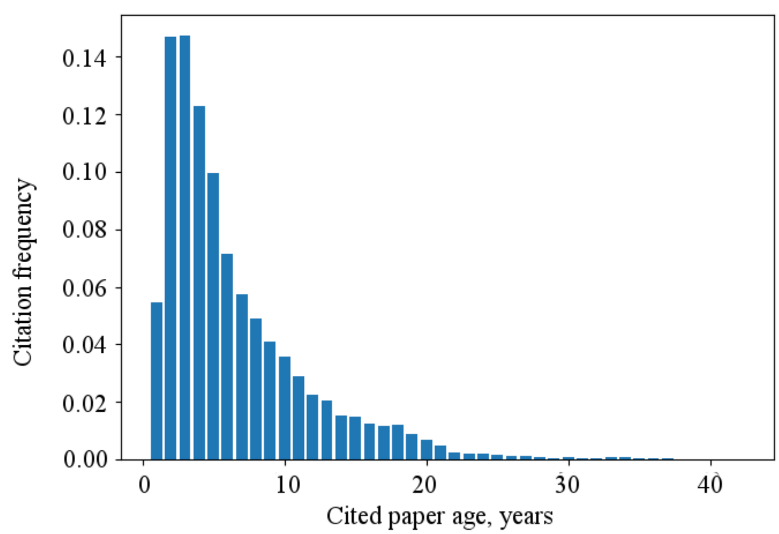


Fig. 5. Frequencies of the citation network edge ages.

The biased seed papers can produce unbiased citation network. To estimate the stability of the restricted snowball sampling with respect to the seed papers variation we run the sampling starting from the full set of the PQA seed papers and mark the relevant papers with main path analysis. Then we run the sampling again starting from 10 random subsets of the PQA seed papers and count the number of the runs where each seminal paper occurs. In our experiments the random subsets contain 50% of the seed papers and 66% of relevant papers are detected every time, 14% – in 80% of runs, 14% – in 60% of runs, 6% – at least once. So we can conclude that the PQA citation network is stable with respect to large seed paper variations being input for the restricted snowball sampling and the result of the sampling is unbiased.

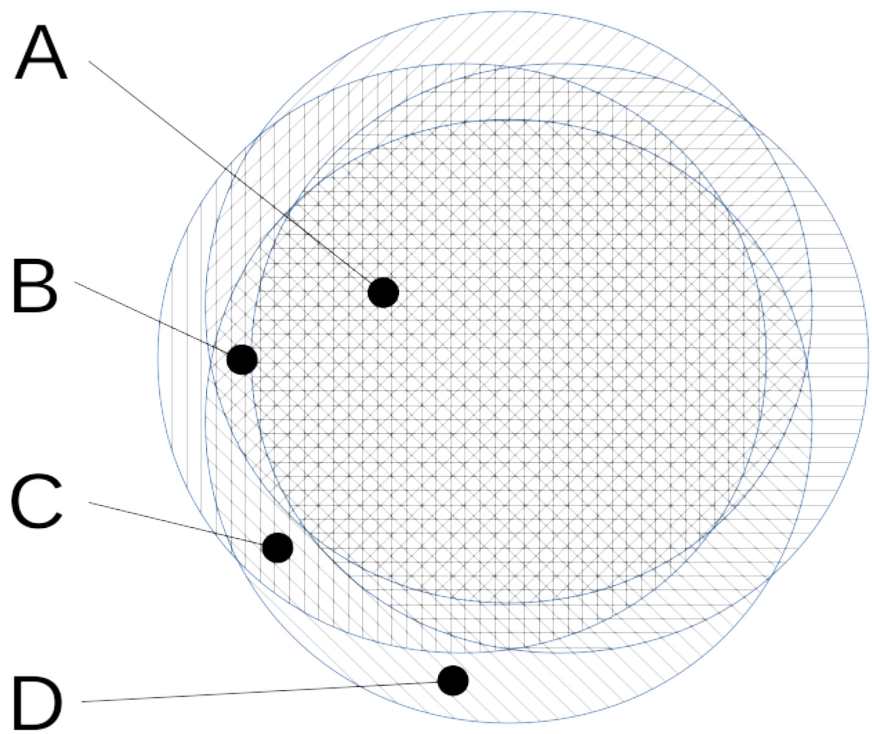


Fig. 6. Probability of the relevant paper detection: A – 66% detected every time; B – 14% detected in 80% of runs; C – 14% detected in 60% of runs; D – 6% detected at least once.

6 Conclusions and Future Studies

The main objective of the paper was to present the complete information technology that obtains a set of publications on some scientific topic as input and produces a list of seminal publications for that topic. It provides data for future detailed analysis and serves as a good point to begin investigation in a new domain. Additionally, we tested several initial assumptions regarding the results of the technology application and show that:

- PTM as a restriction criteria for the restricted snowball sampling method provides adequate semantic distance between publications.
- The restricted snowball sampling guarantees the saturation.
- The maximal number of the references is observed for the publications that are 2–8 years old. Such publications are still regarded as new ones but at the same time are old enough to be read and estimated by many reserchers.

– The biased seed papers produce unbiased citation network.
– The collected citation network is stable with respect to large seed paper variations being input for the restricted snowball sampling and the result of the sampling is unbiased.

The presented technology is implemented as sequence of Python scripts[3].

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Analysis of Completeness, Diversity and Ergonomics of Information Online Resources of Diagnostic and Correction Facilities in Ukraine

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Abstract. In Ukraine, one of the most up-to-date and powerful sources of information for people with special needs is online information resources of state psychological and diagnostic facilities, called PMPK. The most popular online information resources for this category of users are the sites of PMPK and profiles-oriented pages on social networks. These resources were analyzed whether they provide complete information support of each stage of the inclusive education, as well as if their structure and presentation correspond to ergonomic needs and demands of the users with special needs. Both the sites` content presentation and accordance with the existing international ergonomic rules is insufficient. There is no systematic approach to the IT online support for inclusive education processes by means offered by and/or available to PMPK specialists.

To became an institution of professional care of integrated IT support, PMPK system in Ukraine the should involve the specialists of information and communication technologies, methods and means of Big Data analysis. To create the platform of IT support of education of people with special needs at the national level, one should use of a wide range of mobile IT services of prompt and convenient online access to results of psychophysical diagnosis, personal learning trajectories, etc. with full-fledged protection and confidentiality (as an option, the *blockchain* technology was proposed). As the creation and management of own computing infrastructures in PMPC facilities seem to be ineffective and expensive, it is expedient to use technologies and services based on cloud computing models.

Keywords: inclusive education IT support, IT resources ergonomy, blockchain technology.

1. Introduction

In January 2018, the European Commission adopted new initiatives aimed at improving the key and digital competences of European citizens, promoting common values and inclusion. Specialists of the European Commission have been approved a number of documents that reflect the vision of the European Union's future ways of society development: *"Council recommendation on Digital Education Action Plan", "Council Recommendation on promoting common values, inclusive education, and the European dimension of teaching", "Council recommendation on Key Competences for Lifelong Learning"* and others. The recommendations to Member Countries of the European Union (from January 2018) emphasize the need to support the right to quality and inclusive education and lifelong learning by providing opportunities through the development of key competences and basic skills for all, and the special attention must be paid to disadvantaged students [1]. Such students include people with social and economic disadvantages, migrants, people with special needs, as well as talented children [2].

The key competences, promoted by the European Commission, are [1]: literacy – as the basis for the next learning and communication in different social and cultural environments; languages – as a means to better handle the challenges of multilingual modernity; science, technology, engineering and mathematics (STEM) – improvement of achievements in such competences is important for the further education of scientific perception and understanding; digital – increasing confidence and critical use of digital technologies, including programming, as well as security and citizenship; personal, social and learning –as competences, important for active social life; civic – as an emphasis on the importance of democratic processes, European values, sustainable development and media literacy; entrepreneurship – to enable disclosure of its own potential, creativity and initiative; cultural awareness and extension – enhancing intellectual skills and abilities to express ideas in a variety of ways. Key competencies as a combination of knowledge, abilities, and skills, are necessary for personal development, social inclusion, employment and active citizenship [1].

The importance of the inclusive society is also declared in the European Union's Horizon2020 Program. This science and innovation funding program aims to become a key tool for resolving high-priority tasks for Europe. Promoting an inclusive society, Horizon2020 supports measures to overcome social inequality. The program emphasizes the need for innovative approaches to support individuals facing social and digital exclusion, such as older people, the unemployed and poorly educated, migrants, people in need of care, living in remote or poor areas, people with special needs and homeless [3] .

The problems of the European Union countries are relevant also for Ukraine. The need for the socialization of people with special needs, settlers, gifted children are the challenges of a nowadays. The authors payed attention to the inclusion of persons with special needs in Ukraine in the part that deals with the support of such education with information technologies.

2. Types of Information Technology of Education Support of People with Special Needs

The inclusive education is the comprehensive process of ensuring equal access to quality education for persons with peculiarities of psychophysical development, by organizing their studies in *general* educational institutions with the use of personality-oriented teaching methods, taking into account the individual peculiarities of educational and cognitive activity of such persons and the proper medical, social, psychological, pedagogical, organizational and technological support, in the conditions of mass educational establishments in the place of residence [4]. The process consists of four successive stages, the implementation of each stage consists in the step-by-step realization of certain educational tasks related to the organization and support of the education of persons with special needs. In general, the stages of inclusive education are [4]:

Stage 1. Setting the features of the psychophysical development.

Stage 2. Personalization of the educational aims.

Stage 3. Formation of the personalized education trajectory.

Stage 4. The analysis of the realized education trajectory.

The development and implementation of modern comprehensive information technology support for all stages of inclusive education, taking into account the national specifics of such a process, will contribute to more complete and better access to education and social integration of people with special needs, what perfectly complies with the provisions of the framework program [1].

During the study of the support of the education of people with special needs in Ukraine, it was established that the primary institution to which the parents of the child refer, is the diagnostic and correctional institutions – psychological, medical and pedagogical consultations (PMPK). One of the functions of the PMPK, as defined in the Law of Ukraine, is advisory, when the PMPK acts as a source of information. The specialists of such an institution can and should provide advice to participants in the inclusive education process – those with special needs, their parents, inclusive school specialist, administration of the inclusive educational institution, etc. In some cases, the reference component of the operation of the PMPK is implemented, in particular, with the use of information technology.

In general, information technology support for the education of people with special needs varies by a number of factors, that determine the scope of their application. The main groups of this kind of information technology are 1) general-purpose technology, 2) special-purpose technology, 3) technology of communication support and 4) information and technological means of access. To the latter, include online learning management systems and multimedia learning environments, information technologies focused on the needs of the mass school and applicable to the education of people with special needs, mobile applications, and online reference resources. And exactly these online reference resources are the means of the PMPK`s advisory role.

3. Online Reference Resources of State Psychological and Diagnostic Facilities

In Ukraine, the legally fixed structure of PMPK includes central PMPK, republican (AR Crimea), region, Kyiv and Sevastopol city, district (city) PMPKs. There are 618 psychological and medical-pedagogical consultations in Ukraine, of which 27 are regional, including 1 republican, 2 city – Kyiv and Sevastopol) and 591 region (city). The concept of this structure is presented in the form structured tree (Fig. 1).

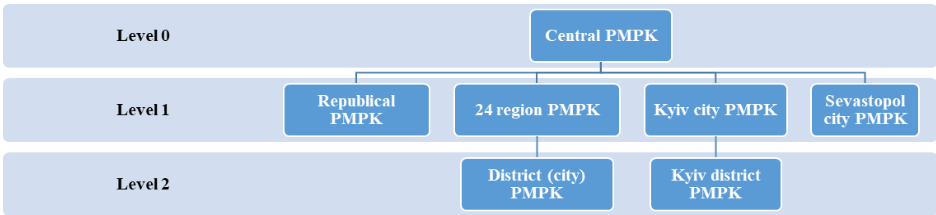


Fig. 1. Concept of Ukraine PMPK structure

4. Research Description

An important task in developing of a complex system of informational and technological support for inclusive education is the compliance with the requirements of availability, completeness, and connection between components of such a system, as well as the ergonomics of its components (in this study, the ergonomic is considered from the angle of perception convenience). Reference online resources of PMPK are an integral part of information and technology support for inclusive education. To assess the relationship between online resources, it is necessary to consider the links between such resources in two directions. According to the concept of the structure of PMPK from Fig. 1, in the horizontal direction there are PMPKs of the same level – for example, the republican PMPK – 24 regional PMPK – Kyiv city PMPK – Sevastopol city PMPK (level 1). In the vertical direction there are PMPKs of different levels, for example, the central PMPK – Vinnytsia Region PMPK – Bershadsky district PMPK.

We shall evaluate the availability of online reference resources to users using the following search criteria:

1. We use search service Google.
2. We use word-for-word information requests in Ukrainian language (for example, “центральна психолого-медико-педагогічна консультація (central psychological-medical-pedagogical consultation)", "Калинівська районна психолого-медико-педагогічна консультація (Kalinovsky district psychological-medical-pedagogical consultation)", etc.).
3. We will analyze the links on the first page of the search results offered by the search service (no more than 10 links).

Taking into account the above requirements, we will evaluate the availability and interconnections between such online resources using algorithm at Fig. 2.

5. The Availability of PMPKs` Online Reference Resources

According to the proposed algorithm, 17 facilities with their own sites were found (PMPKs from levels 0 and 1, according to Figure 1), including 16 regional PMPKs and central PMPK, more than 60% of PMPKs do not have their own online reference resource. Even if such sites exist, their search for the average user is difficult. That is, the sites searching, according to the algorithm proposed in Fig. 2, testified the availability of online reference resources for slightly more than half of PMPKs, conceptually located at levels 0 and 1 (fig. 1).

6. Interconnection of Online Reference Resources of PMPK

Table 1 shows the list of found PMPKs, sorted and grouped by the dates of site creation. The date of creation was determined by the Copyright mark on the site, and if it did not exist, then by the date of the first content placement. Sites are conventionally divided into 4 groups by date of creation: 2009-2012 – 5 sites, 2013-2015 – 4 sites, 2016 – 5 sites, 2017 – 3 sites. The last update was also specified.

Among the found sites of regional PMPK, only 6 resources (37%) have links to the central PMPK, and none of them links to PMPK of the region`s districts. That is, the search for sites according to the algorithm proposed in Fig. 2 witnessed the weak structuring of the system of PMPK`s online reference resources.

7. Analysis of Statistical Indicators of PMPK`s Online Reference Resources

Analysis of statistical indicators of regional PMPK`s sites

The analysis of the statistical indicators of the attraction of users of PMPK sites was carried out using the SimilarWeb Platform [5]. This information technology processes the big data to collect, measure, analyze the behavioral models of sites and users attract. The following characteristics of the PMPK sites were evaluated (in parentheses, the designation of a characteristic):

- Global worldwide rank according to traffic use (a_1).
- Country rank according to traffic use (a_2).
- Site category / rank in category (a_3).
- Total visits (a_4).

For example, for a group of sites created during 2009-2012 (these are the sites of the Central PMPK, as well as Odesa, Kherson, Rivne and Chernivtsi region PMPK) the platform SimilarWeb gave the following estimates (Fig. 3-6):

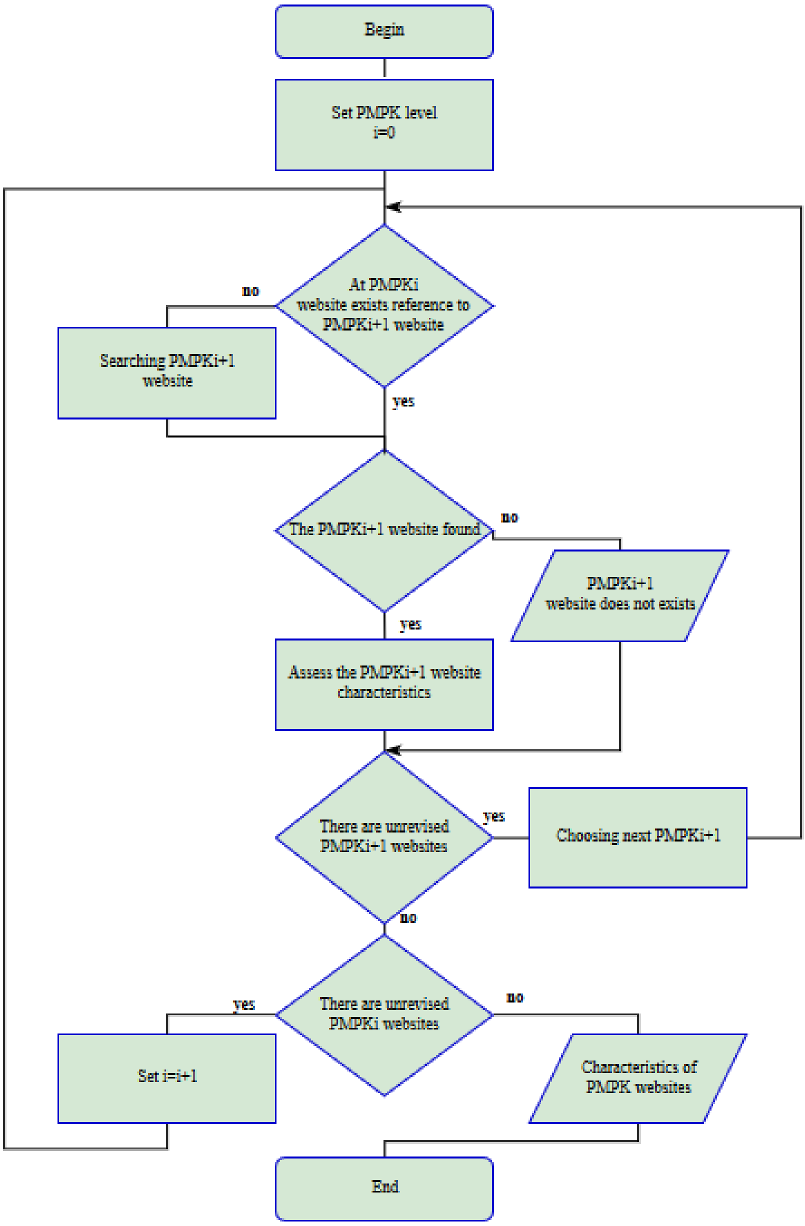
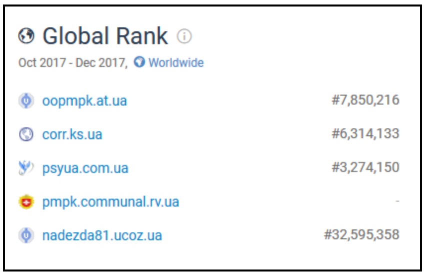


Fig. 2. Availability and interconnections between PMPK`s websites evaluation algorithm

For example, for a group of sites created during 2009-2012 (these are the sites of the Central PMPK, as well as Odesa, Kherson, Rivne and Chernivtsi region PMPK) the platform SimilarWeb gave the following estimates (Fig. 3-6):



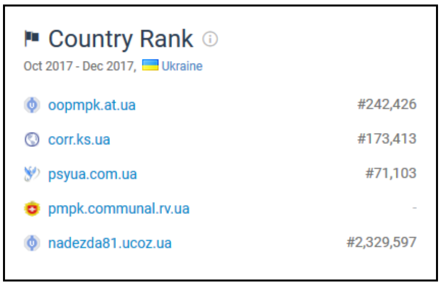


Fig. 3. The assets of the sites` global rank according to the traffic use (by SimilarWeb)

Fig. 4. The assets of the sites` country rank according to the traffic use (by SimilarWeb)

Fig. 5. The assets of the sites` visits peculiarities (by SimilarWeb)

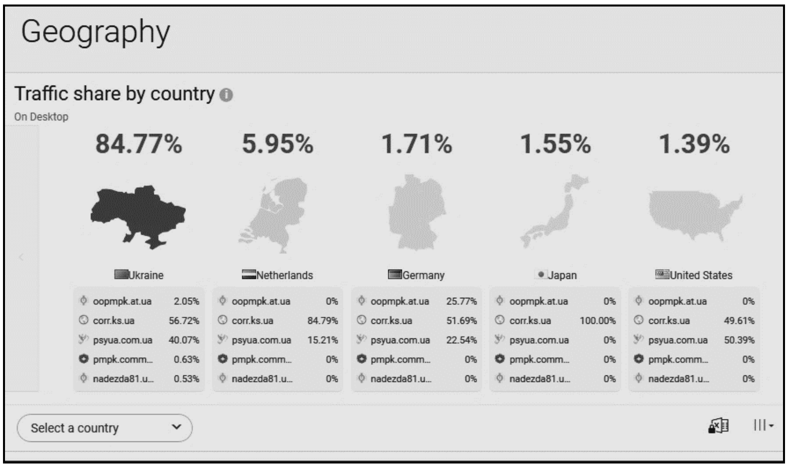


Fig. 6. The assets of the sites` traffic share by country (by SimilarWeb)

The assets of online reference resources for PMPK (level 0-1, fig.1) are summarized in Table 1.

Table 1. Summary characteristics of the sites of regional and central PMPKs (according to the SimilarWeb)

Region PMPK	Site created, year	Last update	a_1	a_2	a_3	a_4
Odesa	2009	2016	7 850 216	242 426	Social sciences / 18552	4 200
Kherson	2010	Jan. 2018	6 314 133	173 413	Social sciences / 15254	38 702
Central	2011	2017	3 274 150	71 103	Internet and communications / 132658	26 010
Rivne	2012	Nov. 2017	N/A	N/A	N/A	190
Chernivtsi	2012	Oct. 2017	32 595 358	2329597	N/A	786
Kirovograd	2013	Dec. 2017	N/A	N/A	N/A	12 100
Kharkiv	2013	Nov. 2017	9 757 084	334 995	Business and industry / 186684	1 800
Donetsk	2015	Apr. 2016	8 297 513	259 415	N/A	2 600
Zakarpattia	2015	Jun 2015	N/A	N/A	N/A	N/A
Vinnytsia	2016	Feb. 2017	N/A	N/A	N/A	391 100
Volyn	2016	2017	N/A	N/A	N/A	214
Dnipropetrovsk	2016	Jan. 2018	N/A	N/A	N/A	10 500
Khmelnytskyy	2016	Feb. 2017	N/A	N/A	N/A	N/A
Cherkasy	2016	Jan. 2018	1 1247 780	406471	News and media / 257359	26 900
Lviv	2017	N/A	N/A	N/A	N/A	38
Luhansk	2017	Oct. 2017	N/A	N/A	N/A	26
Ternopil	2017	Nov. 2017	N/A	N/A	N/A	N/A

From the results, presented in Table 1, it can be drawn the following conclusions.

- Most sites (13 out of 17), at mid-January 2018, content was updated over the past year, with three sites having updated content in 2018.
- For the most sites, created in 2016 and later, it was not possible to establish a global rank in the world and Ukrainian ratings for traffic usage (for October-December 2017).
- Most PMPK sites were not categorized (by SocialWorks), and among classified, there are Internet and telecommunications, Business and industry, News and media, social science categories.
- Number of sites visitors – an average is 32,000 people, with the largest number

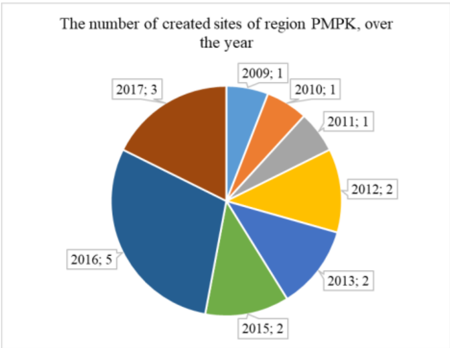


Fig. 7. Comparison of the number of created sites of regional PMPKs

of visits registered for the Vinnytsia PMPK site (created in 2017); the site of Luhansk PMPK had 26 visitors (the site was created in 2017).

- Two of the three most visited sites (Kherson, Vinnitsa and Cherkasy Region PMPKs) were updated in January 2018.
- Starting from 2009, the number of sites, created by PMPK, gradually increased per year, the largest amount sites of PMPKs were created in 2016 (Figure 7).

Analysis of statistical indicators of regional PMPK sites

By the algorithm at Fig. 2, the search for the sites of district (city) PMPKs (level 2 at fig. 1) was performed. Such sites exist in eight regions of Ukraine. The characteristics of the sites of district PMPKs (according to the platform of the SimilarWeb) are presented in Table 2.

From the results presented in Table 2, we can draw the following conclusions.

- The own online reference resources were found for 0.03% of district PMPKs.
- Four regions of Ukraine have one site of the district PMPK.
- The leader in a number of online reference resources is the Kirovograd region, in which 5 of the six regional PMPKs have their own sites (see Fig. 8).
- For most sites, its ranking in the world and Ukrainian traffic usage ratings (for October-December 2017) was not set.
- The average number of visits to the site - 15 thousand visitors, and for the four district PMPK this indicator is zero.
- The biggest activity in creating sites was in 2013-2014, in 2017 no new sites of the district PMPKs were created (fig. 9).

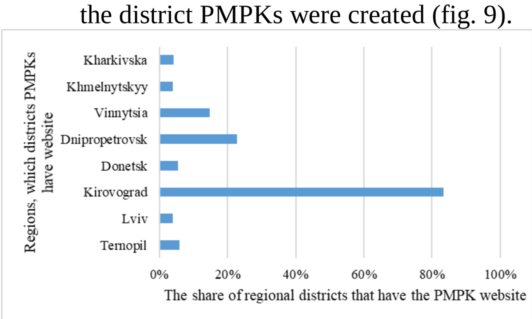


Fig. 8. The ratio of the number of districts of the region and the number of sites of district PMPK

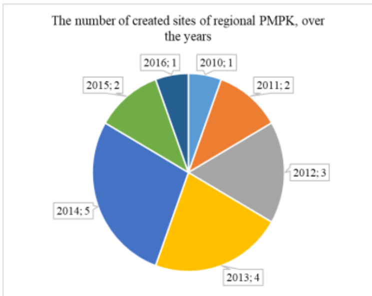


Fig. 9. Comparison of the number of created sites of district PMPK

Table 2. Characteristics of the sites of regional PMPK (according to the similarWeb)

Region	District (city) PMKP	Site created, year	Last update	a_1	a_2	a_3	a_4
Ternopil	Chortkiv	2013	Aug. 2017	N/A	N/A	N/A	38
Lviv	Sokal	2014	December 2017	N/A	N/A	N/A	173600
Kirovograd	Ustyniv	2015	2016	N/A	N/A	N/A	N/A
	Bobrynets	2013	2013	33 bln	2 bln	N/A	164
	Oleksandriya	2014	Dec. 2017	N/A	N/A	N/A	110
	Holovaniv	2015	Dec. 2017	N/A	N/A	N/A	0
	Novyy Myrghorod	2016	Jan. 2018	N/A	N/A	N/A	N/A
Donetsk	Bakhmut	2014	Jan. 2018	N/A	N/A	N/A	0
Dnipropet-rovsk	Dniprodzer-zhynsk	N/A	N/A	N/A	N/A	N/A	211
	Marganets	2012	Dec. 2017	N/A	N/A	People and society	859
	Pyatykhatky	2012	Jan. 2018	N/A	N/A	N/A	9600
	Ingulets	2013	Jan. 2018	N/A	N/A	N/A	3300
	Zhovti Vody	2010	Nov. 2011	N/A	N/A	N/A	
	Novomos-kovsk	2014	Jan. 2018	N/A	N/A	N/A	5500
Vinnytsia	Tyvriv	2011	2017	N/A	N/A	N/A	26
	Bershad	2013	May 2016	N/A	N/A	N/A	0
	Kalyniv	2015	Jan. 2018	N/A	N/A	N/A	0
	Nemuriv	2012	Jan. 2018	2 bln	59830	N/A	22900
Khmelnytsk	Stako-kostiantyniv	2014	Jan. 2018	N/A	N/A	N/A	1300
Kharkiv	Krasnyy Kut	2011	May 2017	N/A	N/A	N/A	50000

8. Assessment of the Ergonomics of PMPK`s Online Reference Resources

The investigated online resources were assessed according to graphic and responsive design demands [6-8] according to the characteristics U_1 – U_6:

U_1 – general composite rules for web sites creation, that are basic for UI / UX (modular content positioning system Modular Grid pattern, Golden Section rule and Fibonacci proportion), which allows to focus on the main and contributes to the perception of content;

U_2 – infographic (information graphics) filling of peculiar sections of the site with graphical visual representation of information, data or knowledge intended for the quick and accurate display of complex information;

U_3 – the presence of interactive animation and video content;

U_4 – a harmonious combination of color schemes (color schemes & palette) that must be presented so as not to violate the basic patterns of color influence on the psychological response of the user;

U_5 – responsive web design, that provides optimal mapping and interaction with the user regardless of the resolution and format of the device, the page is viewed at (tablet, smartphone, etc.);

U_6 – availability of convenient and intuitive forms of feedback, support for thematic forums.

Estimation of the available online reference resources by ergonomic indicators is given in Table 3 (the sign "+" means that the ergonomic characteristic was implemented, "-" its absence, "+/-" denotes the partial implementation of the characteristic). Graphic presentation of the results is at Fig. 10. The resources were also checked, using the Web Content Accessibility Guidelines (WCAG) 2.0 [9] (using http://www.atutor.ca/achecker/ open source as an evaluation tool).

Table3. The presence of ergonomic characteristics at PMPK sites

Region PMPK	U_1	U_2	U_3	U_4	U_5	U_6	Known problems	Potential problems
Odesa	-	-	-	-	-	-	18	191
Kherson	+/-	-	-	+/-	-	+/-	33	149
Central	-	-	-	-	-	-	58	308
Rivne	-	-	-	+/-	-	+/-	13	99
Chernivtsi	-	-	-	-	-	+/-	0	0
Kirovograd	+/-	-	-	+/-	+	+/-	18	359
Kharkiv	+/-	-	-	-	+	-	9	455
Donetsk	+/-	-	-	-	+	-	0	0
Zakarpattia	-	-	-	+/-	-	-	0	34
Vinnytsia	+/-	-	-	-	+	-	14	534
Volyn	-	-	-	-	-	+/-	0	34
Dnipropetrovsk	+/-	-	-	+/-	-	-	0	0
Khmelnytskyy	-	-	-	-	+/-	-	245	141
Cherkasy	+/-	-	-	-	-	+	17	168
Lviv	+/-	-	-	+/-	-	+/-	7	137
Luhansk	-	-	-	+/-	-	+/-	0	34
Ternopil	-	-	-	-	-	-	48	153

Concerning the ergonomics of the investigated sites, the authors reached the following conclusions:

- the vast majority of sites do not meet the modern requirements, relating to the design of the site at the stage of their creation;
- the most of the sites are non-adaptive, that is, they do not have mobile versions or versions for viewing on tablets;
- compliance with compositional rules and positioning content on a modular principle is conditional;
- the color schemes were not given appropriate attention;
- the infographical content and animation/video content is absent;
- the unification of the content of such sites is insufficient.

The number of known and potential problems, according to WCAG 2.0, evaluated for each site, shows that site developers in six regions were aware of the web content accessibility demands.

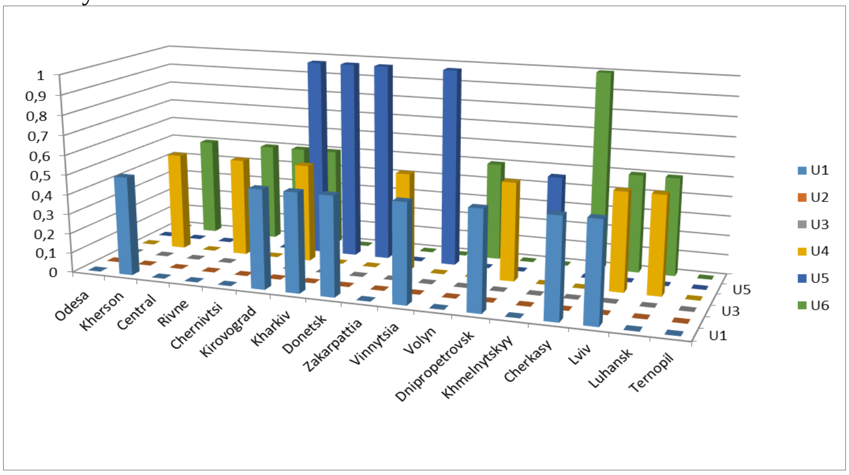


Fig. 10. Graphical representation of the results of the study of the ergonomics of PMPK sites

In view of the results, the authors consider it advisable to propose the development of a Wireframe for users with special needs (a general representation of the information structures of the site), followed by its prototyping. This will allow to get a highly distributed representation of the desired website (while taking into account general compositional techniques and modular content positioning), it is crucial to test the interaction of the user with the interface of the final product. The authors plan to develop and implement an adaptive site template based on HTML/CSS/JS with the ability to fill the content for the demands of people with special needs. It will be possible to choose harmonious color schemes, corresponding typographic styles. The developed technology will be adjusted to WCAG 2.0.

9. The Completeness of Inclusive Education Support by the Online Reference Resources of PMPK

On the sample of the regional PMPK sites, the authors performed the evaluation of the completeness of the support of inclusive education process – from the definition of the features of the psychophysical development of the person, the personalization of the purpose of teaching the person, taking into account the correctional component of the training, the formation of the personal trajectory of education, to the analysis of the outcomes of the implemented educational trajectory.

For each of the stages of the inclusive education, was identified the content of the PMPK website, which is needed to support the education of people with special needs [4]. Table 4 also has corresponding formal designations.

Table 4. Content at PMPK sites to support inclusive education

Stages of inclusive education	Content at PMPK sites to support inclusive education	Formal designation
Stage 1. Setting the features of the psychophysical development.	-Timetable of the PMPK and its specialists	w_{11}
	-Contacts, options for available transport connection	w_{12}
	-Information and contacts of the PMPK of the higher level	w_{13}
	-Road map of peculiarities of person's psychophysical development - by nosology, for specialists and non-specialists	w_{14}
	-Reference information about existing education formats	w_{15}
	-Innovations in the specifics of education for children with special needs	w_{16}
	-Legislative support for the education of people with special needs	w_{17}
Stage 2. Personalization of the educational aims.	-Typical curricula	w_{21}
Stage 3. Formation of the personalized education trajectory.	-Up-to-date events for people with special needs	w_{31}
Stage 4. The analysis of the realized education trajectory.	-Road map of peculiarities of person's psychophysical development - by nosology, for specialists and non-specialists	w_{41}
Characteristics of an online resource as an information portal	-Feedback available	w_a
	-Forums	w_b

Estimation of the available online reference resources by the presence of the content of the inclusive education support is given in Table 5 (the "+" sign means the presence of content on the site, "-" its absence). In the future, such evaluation will be provided using linguistic variables for natural language assessment for further application in computing systems.

From the analysis of the results, presented in Table 5, authors can draw the following conclusions about the functioning of the online reference resources of the PMPK in Ukraine:

- Existing websites contain disconnected, not unified information; the content is given at the subjective taste of website`s creator.
- There is no regional PMPK website, that would provide comprehensive background support for each stage of inclusive education;
- Almost all sites have no characteristics of information platforms – i.e. they do not support the ability to contact PMPK specialists and site authors;
- The common features of such sites are the availability of information about the timetable for the work of the PMPK, its specialists, as well as the contacts and variants of available transport links with the institution;
- There are no links between the sites in the horizontal direction, that is, the sites of regional PMPK do not contain links to sites of other regional PMPKs.

Table 5. Presence of content at PMPK websites

Region PMPK	Site created, year	w_{11}	w_{12}	w_{13}	w_{14}, w_{41}	w_{15}	w_{16}	w_{17}	w_{21}	w_{31}	w_a	w_b
Odesa	2009	+	+	-	-	+	+	-	-	-	+	+
Kherson	2010	+	+	+	+	-	+	-	-	+	+	-
Central	2011	+	+	-	-	-	+	-	-	-	-	-
Rivne	2012	+	+	+	+	+	+	+	-	+	-	-
Chernivtsi	2012	+	+	-	+	-	+	+	-	-	+	-
Kirovograd	2013	+	+	+	+	-	+	+	-	-	+	+
Kharkiv	2013	+	+	-	+	+	+	+	-	+	-	-
Donetsk	2015	+	+	+	+	+	+	-	-	+	-	-
Zakarpattia	2015	+	+	-	+	+	+	+	-	-	-	-
Vinnytsia	2016	+	+	-	-	-	+	+	-	+	+	-
Volyn	2016	+	+	-	+	+	+	-	-	-	+	-
Dnipropet-rovsk	2016	+	+	+	-	-	-	+	-	-	+	-
Khmelnyts-kyy	2016	+	+	+	+	+	-	+	-	-	-	-
Cherkasy	2016	+	+	-	-	+	-	-	-	-	-	-
Lviv	2017	+	+	-	-	-	-	-	-	-	+	-
Luhansk	2017	+	+	-	-	-	-	-	-	-	+	-
Ternopil	2017	+	+	-	+	-	+	+	-	-	-	-

- There are no links between the sites in the horizontal direction, that is, the sites of regional PMPK do not contain links to sites of other regional PMPKs.
- About one-third of available PMPK websites have links to top-level PMP sites (vertical direction).
- Although the central PMPK declares contact with regional PMPKs, however, it is only a reference to non-existent pages or to websites, where the PMPK and its activities are mentioned in passing;
- All of the above findings indicate a lack of a system-wide national approach to the information support system of the PMPK - as an integral part of IT support for education of people with special needs.

Creating of unified PMPK web-portals, which would provide full content to support the education of people with special needs and meet requirements, mentioned in the article, is an integral part of the development of a comprehensive nationwide system of information and technology support for inclusive education. It should also be taken into account that the components of information content can be divided into two groups. The first group include the stable, rarely changed components for the inclusive education process in Ukraine – i.e., this information should be identically presented in all PMPKs` websites: road map of peculiarities of person's psychophysical development e.g. by nosology, for specialists and non-specialists (w_{14}), reference information about existing education formats (w_{15}), legislative support for the education of people with special needs (w_{17}), typical curricula (w_{21}). The second group includes all other components of the information content of the PMPK sites, which are individual for each PMPK – its address, contacts, news, etc. Such features of the content of PMPK sites, due to the peculiarities of information support for the education of persons in the format of inclusion, should be taken into account when improving the information resources of PMPK.

The reform of PMPK in Ukraine and its transformation to a level of institution, that would professionally care of information technology support of the education of persons with special needs, provides for the involvement of professionals with a wide range of knowledge, particularly in the field of information and communication technologies, methods and tools of Big Data analysis, as mentioned, in particular, in [10]. The complex data sets are accumulated at all the stages of inclusive education, and analysis such data using Big Data analysis techniques will allow to define the level of person`s psychophysical development, to develop personalized educational trajectory, as well as analyze both educational and correctional outcomes. Creating a nationwide platform of information technology support of the education of persons with special needs, according to the authors, should be performed using a wide range of mobile IT services, enabling quick and easy online access to shared information resources, including the results of psychophysical diagnosis, personal education trajectories, etc. with full-featured protection and privacy (authors agree with [10] which mentions the possibility of *blockchain* technology implementation). However, it seems ineffective to deploy computing infrastructures in PMPK facilities, instead of which will be better to use the technologies and services, based on cloud computing model. This approach would help to simplify and reduce significantly the cost, the organizational and operation deployment of a complex system of integrated information technology to support the processes of inclusion of people with special needs across the country.

Currently, the authors are actively researching the possibilities of building the architecture of such a comprehensive information and technology platform of national scale, and are working out possible ways to create software and algorithmic tools for its effective implementation.

10. Conclusions

One of the most up-to-date and powerful sources of information for people with special needs in Ukraine are online reference resources of state psychological and diagnostic facilities – psychological, medical and pedagogical consultations (PMPK). The PMPK`s sites are to be the most available online information resource for this category of users.

The results of the conducted research suggest that in the procedures of information and technology support of the education of people with special needs by means offered and/or available to PMPK specialists, there is no systematic approach to the implementation of the functions of informational and technological online support for inclusive education processes. Being disparate, the available IT support is realized with paying almost no attention to the existing ergonomic rules for the content presentation for people with special needs.

More than 60% of regional PMPK facilities have their own website, and it is less than half the percent of regional PMPKs, that have their website. Authors came into conclusion, that the development of such websites requires centralized management of to unify the information, important for the education of people with special needs. It also makes it possible, in a certain way, to simplify the process of developing online resources for PMPKs of all levels, and especially for smaller facilities, less than a percent of which has such a site by now.

The proposed study on the availability, completeness, integrity, content availability and ergonomics of PMPK online information resources should be conducted periodically to track the dynamics of changes in the characteristics of support of education of people with special needs by information technologies.

Prospects for future research are the development of requirements for the creation of a system of online reference resources of correctional facilities, taking into account the WCAG 2.0 Web Content Accessibility Guidelines. To extend the completeness of the analysis of online PMPK resources, it is advisable to introduce additional characteristics of sites to determine the features of developing such resources. It is expedient to process the obtained empirical data, for example, by methods of data analysis or descriptive statistics. The use of cloud technologies for centralized accumulation, processing of information with next processing such Big Data can be a convenient approach for organizing and maintaining a complex system of holistic information and technology complex supporting of the processes of inclusive.

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Fuzzy Technology-Based Cause Detection of Structural Cracks of Stone Buildings

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Abstract. The article presents a hierarchical fuzzy rule base for intelligent support of decision making about cause of structural crack of stone building. According to civil engineering practice the causes of structural cracks are classified by the followings diagnoses: static overload; dynamic overload; especial overload; defects of basis and foundation; temperature influence; breach of technological process during the building. Source information needed for decision making is the data of visual investigation of building, icluding simple measuremnts. For decision making we take into account 42 input attributes. The hierarchical system ties 9 fuzzy knowledge bases, which contain 151 rules in total. Cause detection of the crack is carrying out by max-min fuzzy inference with hierarchical knowledge base. Learning of fuzzy rules by genetic algorithms provided a good matching between real causes of cracks and modeling results.

Keywords: fuzzy technology, fuzzy inference, fuzzy rule, hierarchical knowledge structure, diagnosis, structural crack, stone construction.

1 Introduction

Instant and correct diagnosis of the stone construction cracks makes further investigations, design and reconstruction of buildings successful. The task of diagnosis may be solved correctly by high qualification engineers with huge experience. The number of such experts is lacking, hence the creation of decision making model for diagnosis of structural cracks of buildings is necessity.

One of the most promising ways to processing uncertain expert information is fuzzy sets theory [12]. Application of fuzzy sets for diagnosis of building constructions was started in 1982 [6]. It used a fuzzy inference for assessment of structural damages after an earthquake. Later, articles showed the successful applications of fuzzy inference for diagnosis the cracks in reinforced concrete structures [3], for assessment of building damage and safety after an earthquake [4], for damage identification in Timoshenko beam-type structures with cracks [2], and for concrete bridge damage diagnosis and prediction which aims to provide bridge designers with valuable information about the impacts of design factors on bridge deterioration [13]. In building diagnosis also is accepted and other kind of a fuzzy information processing, for example, a fuzzy signature rule base for hierarchical decision making on renovating or replacing the historical buildings [9], and fuzzy integrals and fuzzy arithmetic for seismic resilience assessment of bridges [1].

This paper presents a hierarchical fuzzy rule base and corresponding technology for decision making support about the cause of stone construction crack of building. The used approach to fuzzy diagnosis model design is based on a conception of creation and learning the hierarchical fuzzy rule base. The general conception of identification of multifactor dependences with hierarchical fuzzy rule base is described in article [9]. The conception consists of carrying out the following stages: 1) description of decision making process in form of inference tree; 2) presentation of input attributes in linguistic variable form; 3) formalisation of linguistic terms by fuzzy sets; 4) formalisation of expert nature language expressions about "attributes – diagnosis" relationship by fuzzy rule bases; 5) learning the hierarchical fuzzy rule base by genetic optimization.

2 Formalisation of the Diagnosis Problem

According to civil engineering practice different causes of structural cracks of stone building are classified by the followings diagnoses:

d_1 – static overload;
d_2 – dynamic overload;
d_3 – especial overload;
d_4 – defects of basis and foundation;
d_5 – temperature influence;
d_6 – breach of technological process during the building.

The suggested classification accords to maximal depth of diagnosis, which can be got for case of visual investigation of the building. The input attributes are as follows:

x_1 – construction type;
x_2 – work condition;
x_3 – thickness of horizontal junctures;
x_4 – defects of junctures filling;
x_5 – defects of bandaging system;
x_6 – unforeseen holes;
x_7 – defects of reinforcing;
x_8 – curve of construction;
x_9 – deflection from vertical line;
x_{10} – moistening of brickwork;
x_{11} – peeling of brickwork;
x_{12} – weathering of brickwork;
x_{13} – leaching of brickwork;
x_{14} – crumbling of brickwork;
x_{15} – crack location;
x_{16} – crack direction;
x_{17} – opening of crack;

x_{18} – crack width;
x_{19} – crack length;
x_{20} – consequences of fair;
x_{21} – information about earthquakes, explosions;
x_{22} – presence of dynamic load;
x_{23} – splitting under straight;
x_{24} – crack depth;
x_{25} – displacement of breast-wall;
x_{26} – damage of water-supply system;
x_{27} – quality of drains;
x_{28} – presence of loose soils;
x_{29} – presence of water in cellar;
x_{30} – presence of capacitevy construction close;
x_{31} – presence of new adjacent buildings;
x_{32} – displacement of straight, beam;
x_{33} – necessity of sedimentary juncture;
x_{34} – presence of sedimentary juncture;
x_{35} – presence of additional loads;
x_{36} – presence of mechanical damages;
x_{37} – quality of cushions under beams;
x_{38} – insufficient size of beans bearing place;
x_{39} – necessity of temperature juncture;
x_{40} – presence of temperature juncture;
x_{41} – execution of works on winter;
x_{42} – using of heterogeneous materials.

Creation of the diagnostic model for crack cause detection is reduced to finding out the mapping of this form:

$$X = (x_1, x_2, ..., x_{42}) \rightarrow D \in \{d_1, d_2, d_3, d_4, d_5, d_6\},$$

where X denotes a vector of the input attributes and D denotes a cause of the crack.

3 Fuzzy Inference Tree

Hierarchical interconnection between input attributes (X) and cause of crack (D) is represented in the form of a fuzzy inference tree (Figure 1). Graph vertices are interpreted in the following way: the squares – possible causes of the crack; the circles – input attributes; the double circles – fuzzy rule bases. Enlarged attributes, to which edges correspond, as going out of nonterminal vertices are interpreted as followings:

y_1 – state of construction;
y_2 – destruction of brickwork;
y_3 – extra support for some cause;
y_4 – support for basis and foundation defects;
y_5 – possibility of static overload;
y_6 – demand to temperature juncture;

y_7 – support for of crack connected with breach of technological processes;

y_8 – demand to sedimentary juncture.

The hierarchical structure of decision process makes the diagnostic model more interpretable and more compact. The hierarchical structure reflects expert knowledge and information from a lot of special books and articles about crack dynamics.

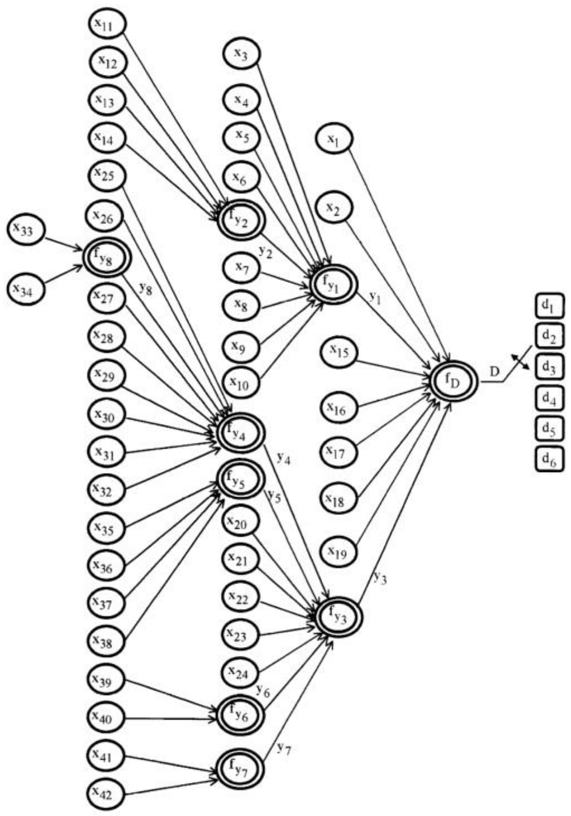

Fig. 1. Fuzzy inference tree

4 Fuzzy Rules

The attributes are represented as linguistic variables. The following 117 terms are used for linguistic assessment of input attributes:

x_1 – {deaf wall (DW), wall with pilaster (WP), pier (P), deaf partition (DP), pier with aperture (PA), wall with aperture (WA)};

x_2 – {holding (H), self-holding (SH), non-holding (NH)};

x_3 – {normal (N), excessive (E), very excessive (VE)};

x_4, x_7, x_9 – x_{14} – {absence (A), minor (M), significant (S)};

x_5, x_6 , x_8, x_{20} – x_{23}, x_{25}, x_{26}, x_{29}, x_{31}, x_{32}, x_{35}, x_{36}, x_{38} – {absence (A), present (P)};

x_{15} – {across whole wall (AW), between walls (B), borders of wall (BW), from monolithic inclusion (MI), at supports (S), top of construction (TC), free field (FF), bottom of construction (BC)};

x_{16} – {vertical (V), oblique (O), horizontal (H)};

x_{17} – {up, slanting (S), down (D)};

x_{18} – {hair (H), small (S), average (A), large (L), very large (VL)};

x_{19} – {short (S), average (A), long (L), very long (VL)};

x_{24} – {one-sided (OS), through (T)};

x_{27} – {low (L), excellent (E)};

x_{28}, x_{30}, x_{41}, x_{42} – {absence (A), uncertainly (U), present (P)};

x_{33}, x_{39} – {unnecessary (UN), necessary (N)};

x_{34}, x_{40} – {absence (A), low quality (LQ), quality (Q)};

x_{37} – {low (L), high (H)}.

The following 24 terms are used for linguistic assessment of enlarged attributes:

y_1 – {normal (N), weak (W), very weak (VW)};

y_2 – {absence (A), medium (M), heavy (H)};

y_3 – {absence (A), static overload (SO), dynamic overload (DO), especial overload (EO), defects of basis and foundation (BF), temperature influence (T), breach of technological process of building (TP)};

y_4 – {absence (A), low (L), high (H)};

y_5, y_7 – {absence (A), present (P)};

y_6, y_8 – {observed (O), ignored (I)}.

Formalisation of linguistic terms of input attributes is carried with bell-shaped membership function with 2 parameters: b – core of the fuzzy set and c – concentration of membership curve.

Natural language expert expressions, which tie up the attributes and output variable, are formalised in fuzzy rule base form. Tables 1 – 9 show some fragments of the rule bases. In the tables the symbol "–" is equal to membership function *“Do not care”* [5]. We use 49 rules in D-base, 31 rules in y_1-base, 15 rules in y_2-base, 16 rules in y_3-base, 20 rules in y_4-base, 6 rules in y_5-base, 4 rules in y_6-base, 6 rules in y_7-base, and 4 rules in y_8-base. Total number of rules of all the bases is 151.

Table 1. Fragment of fuzzy rule base about diagnoses

x_1	x_2	y_1	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	y_3	D
–	H	–	S	–	up	–	–	SO	d_1
WP	H	W	S	O	up	H	–	A	d_1
–	–	VW	AW	O	–	–	–	SO	d_1
WA	H	W	AW	O	S	H	VL	DO	d_2
–	–	–	BW	V	up	H	–	DO	d_2
DW	H	–	B	O	up	–	–	EO	d_3
–	H	–	S	V	up	A	L	EO	d_3
WA	H	–	AW	V	up	L	VL	A	d_4
–	–	VW	AW	O	–	–	–	BF	d_4

x_1	x_2	y_1	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}	y_3	D
–	SH	W	B	V	up	H	–	A	d_4
DW	H	–	BC	V	D	L	–	BF	d_4
–	–	–	TC	V	up	–	–	BF	d_4
–	–	–	TC	V	up	–	–	BF	d_4
DW	–	W	BC	O	–	–	–	BF	d_4
DP	NH	W	AW	H	S	A	VL	BF	d_4
–	SH	N	TP	O	up	S	L	T	d_5
WA	SH	–	FF	O	S	H	–	T	d_5
P	H	–	MI	O	up	H	A	TP	d_6
PA	NH	VW	TC	O	up	S	A	TP	d_6

Table 2. Fragment of fuzzy rule base about enlarged attribute y_1

x_3	x_4	x_5	x_6	y_2	x_7	x_8	x_9	x_{10}	y_1
N	A	A	A	A	A	A	A	A	N
N	H	P	A	A	A	A	A	A	W
VE	H	A	A	A	A	A	A	A	W
N	M	A	A	M	A	A	A	M	W
VE	–	P	P	–	–	–	–	–	VW
E	S	P	–	–	S	P	–	S	VW
–	S	–	–	–	M	P	M	–	VW

Table 3. Fragment of fuzzy rule base about enlarged attribute y_2

x_{11}	x_{12}	x_{13}	x_{14}	y_2
A	A	A	A	A
S	A	A	A	M
A	A	A	M	M
S	M	M	–	H
M	M	M	M	H
S	S	S	S	H

Table 4. Fragment of fuzzy rule base about enlarged attribute y_3

y_4	y_5	x_{20}	x_{21}	x_{22}	x_{23}	x_{24}	y_6	y_7	y_3
A	A	A	A	A	A	OS	O	A	A
–	P	–	–	–	–	–	–	–	SO
–	–	–	–	P	–	–	–	–	DO
–	–	–	P	–	–	–	–	–	EO
H	–		–	–	–	–	–	–	BF
L	A	P	A	A	P	T	O	A	BF
–	–	–	–	–	–	–	I	–	T
–	–	–	–	–	–	–	–	P	TP

Table 5. Fragment of fuzzy rule base about enlarged attribute y_4

x_{25}	x_{26}	y_8	x_{27}	x_{28}	x_{29}	x_{30}	x_{31}	x_{32}	y_4
A	A	O	E	A	A	A	A	A	A
A	A	O	E	A	A	P	A	A	L
P	–	–	–	–	–	–	–	–	H
–	P	–	–	–	–	–	–	–	H
–	–	I	–	–	–	–	–	–	H
–	–	–	L	–	–	–	–	–	H
–	–	–	–	P	P	–	–	–	H
–	–	–	–	U	P	–	–	–	H
–	–	–	–	–	P	P	–	P	H
–	–	–	–	–	–	–	P	P	H

Table 6. Fuzzy rule base about enlarged attribute y_5

x_{35}	x_{36}	x_{37}	x_{38}	y_5
A	A	A	A	A
P	–	–	–	P
–	P	–	–	P
–	–	P	–	P
–	–	–	P	P
P	P	P	P	P

Table 7. Fuzzy rule base about enlarged attribute y_6

x_{39}	x_{40}	y_6
N	Q	O
UN	–	O
N	A	I
N	LQ	I

Table 8. Fuzzy rule base about enlarged attribute y_7

x_{41}	x_{42}	y_7
P	–	P
–	P	P
A	A	A

Table 9. Fuzzy rule base about enlarged attribute y_8

x_{33}	x_{34}	y_8
UN	–	O
N	Q	O
N	A	I
N	LQ	I

5 Decision Making

Decision making about diagnosis is carried out according to the following algorithm:

1. Fix the input attributes of the diagnosis object.
2. Make up a fuzzification i.e. find input attributes membership degrees to linguistic terms and present results in form of bifuzzy sets. Adjective "bifuzzy" [7] emphasizes that fuzzy set support consists of fuzzy sets. In our case, support of the bifuzzy set equals the term-set.
3. Make up a fuzzy inference for all fuzzy rule bases.
4. Choose the decision from set $\{d_1, d_2, d_3, d_4, d_5, d_6\}$ with the maximum membership degree.

During the fuzzification the membership degrees of input attributes to terms from rule base are calculated taking into account crisp and fuzzy values. For crisp source data, membership degree is calculated by the substitution of the current value of the input attribute into membership function. It is possible to use the linguistic values for input attributes. In this case the linguistic values is taken from the term-set of relevant variable. Hence, the linguistic value became equals to some fuzzy set. For fuzzy source data, the membership degree of one fuzzy set (the value of an input attribute) to another fuzzy set (a term from a rule base) must be calculated. According to [10], the membership degree equals the height of intersection of these fuzzy sets (Figure 2). If the both fuzzy sets are represented bell-shaped membership functions with coefficients (b_1, c_1) and (b_2, c_2), then the height of their intersection may be calculated by following fast formulae:

$$height = \frac{1}{1 + \min\left(\frac{b_1 - b_2}{c_2 \pm c_1}\right)^2}.$$

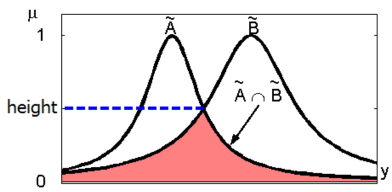

Fig. 2. Calculation of membership degree of fuzzy set $\tilde{A}$ to fuzzy set $\tilde{B}$

Fuzzy inference is carried according to tree from Figure 1. Operations fuzzification – defuzzification are not employed for enlarged attributes (Figure 3). The result of fuzzy inference on the lower level in form of fuzzy set is passed directly into inference machine at higher level. Fuzzy output value at lower hierarchical level is considered as input fuzzy value at higher hierarchical level. In this case, membership functions for terms of the conjuncted variables (enlarged attributes) are unnecessary. We have selected the following inference options: minimum as t-norm and single winner rule [5] as aggregation.

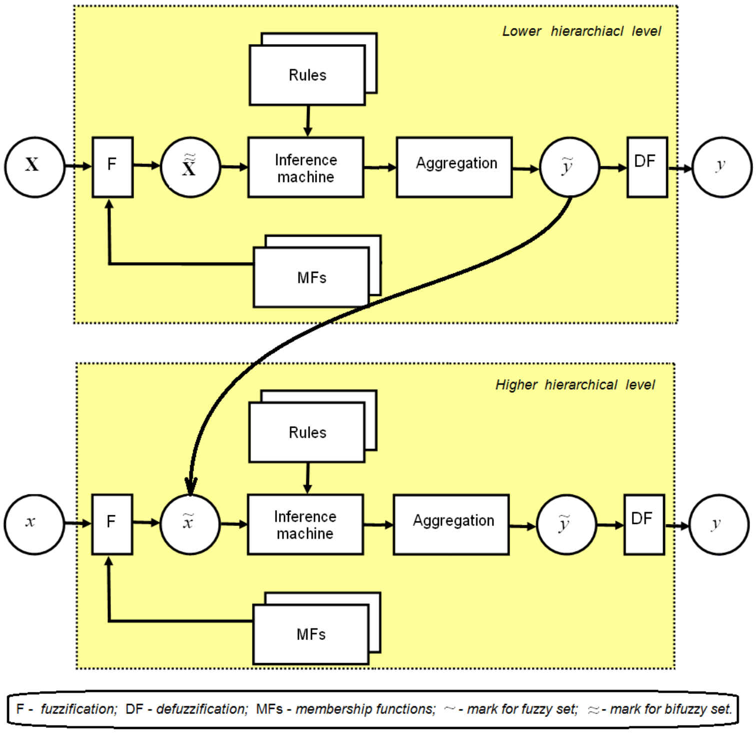

Fig. 3. Hierarchical fuzzy inference

6 Learning the Hierarchical Fuzzy Rule Base

Learning is the process of finding out such values of model parameters which provide shortest distance between results of modeling and experimental data. The tuning parameters are membership functions coefficients (*b* and *c*) and weight factors of fuzzy rules. The total number of these parameters is 2*117+151=385. For reducing the learning complexity we will not change weight factors for 23 absolutely-reliable rules. According to interpretability saving scheme in [11] we will not change coefficients *b* for membership functions extreme terms such as *Low* and *High*. There are 2*42=84 extreme terms for input attributes $x_1 - x_{42}$. Hence, total number of the tuning parameters becomes equal to 385–23–84=278. The quantity of the tuning parameters is large, because of for solving this nonlinear optimization task we employed genetic algorithms. For overfitting prevention we setup the narrow changing bounds of membership functions coefficients.

After learning, the misclassification rate is about 4.5%. There are 4 wrong inferred decisions out 89 testing cases. Note, that for these 4 cases the inferred decision with the second rank is correct.

7 Conclusions

We described the hierarchical fuzzy rule base for decision making support about cause of structural crack of stone building. Different causes of structural cracks are classified by the followings diagnoses: static overload; dynamic overload; especial overload; defects of basis and foundation; temperature influence; breach of technological process during the building. For decision making we use 42 input attributes. The hierarchical system ties 9 fuzzy knowledge bases, which contain 151 rules. The hierarchical structure of decision making process makes the diagnostic model more interpretable and more compact. Learning of fuzzy rules by genetic algorithms provided a good concordance between real causes of cracks and modeling results with misclassification rate at level of 4.5%. The design of our inferring model for stone construction crack diagnosis suggests a general approach to expert systems design in other diagnostic fields.

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Optimization of Parallel Software Tuning with Statistical Modeling and Machine Learning

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Abstract. High-performance computation is the main goal of parallel computers, but the performance of compiled code is often far from the best. Parallel program auto-tuning is the method adjusting some structural parameters (mainly, data structures) of an application program for a target hardware platform to speed-up computation as much as possible. In previous work, the authors have developed a framework intended to automate generation of an auto-tuner from an application source code. However, auto-tuning for complex and nontrivial parallel systems is usually time-consuming due to empirical evaluation of huge amount of parameter values combinations of an initial parallel program in a target environment. In this paper, we propose to improve the auto-tuning method using statistical modeling and neural network algorithms that allow to reduce significantly the space of possible parameter combinations. The resulting optimization is illustrated by an example of tuning a parallel sorting program, that combines several sorting methods. The optimization is done by means of the automatic training of a neural network model on results of "traditional" tuning cycles with subsequent replacement of some auto-tuner calls with an evaluation from the statistical model.

Keywords. Auto-tuning, parallel computation, machine learning, neural network, statistical modeling.

1 Introduction

The problem of optimal use of computing resources has always been important in the process of development of any software — from mobile applications to complex client-server systems. The auto-tuning paradigm [1, 2], which has become a standard for solving the problem of software application optimization over the last decade, allows to fully automatize this process for any computing environment. Its popularity is predefined first by simplicity of use and independence from qualitative characteristics of a computer and operating system. Auto-tuning traditionally uses empirical data for obtaining a qualitative evaluation of optimized code (the quality usually refers to program execution time and accuracy of output results). It automates the search for the optimal program version out of a set of provided possibilities by running each candidate and measuring its performance on a given parallel architecture. Its main benefit is a high level of abstraction — a program is optimized without explicit knowledge of hardware implementation details, such as number of cores, cache size or memory access speed on various levels. Instead, it needs to use subject domain concepts such as number and size of independent tasks.

In the previous works [3–6], we have developed a theory, methodology and tools for automated program design, synthesis, and auto-tuning, based on Glushkov's systems of algorithmic algebras (SAA) and term rewriting technique. The model for parallel programs optimization and the auto-tuning framework named TuningGenie aimed at automating adjustment of programs to a target platform have been proposed in [6]. The framework works with a source code of parallel software and performs source-to-source transformations by using facilities of a rule-based rewriting system TermWare [3].

The main drawback of the auto-tuning approach is in significant one-time costs of optimization process: if the number of program versions is large enough, the optimization process may run for many hours and even days. In this paper we propose the hybrid approach to auto-tuning using statistical modeling and machine learning technique to reduce the time needed for searching for an optimal program version. The approach consists in automatic training of a neural network model on results of common tuning cycles with subsequent replacement of some auto-tuner calls with an evaluation from the statistical model.

2 Auto-Tuning Software Framework and Machine Learning

In the work [6], TuningGenie framework for automated generation of auto-tuner applications from a source code has been developed. The idea of an auto-tuner consists in empirical evaluation of several versions of input program and selection of the best one where the main evaluation criteria are less execution time of input program and accuracy of results obtained. The framework works with program source code using expert knowledge of a developer and automation facilities from the framework. A developer adds some metadata (parameter names and value ranges) to a source code in the form of special comments-pragmas. Exploiting such expert knowledge (s)he can reduce the number of program versions to be evaluated and therefore increase optimization performance.

The auto-tuning software implementation is based on the rewriting rules system TermWare [3]. TermWare is an open-source implementation of rewriting rules engine written in Java. It provides a language for describing rewriting rules that operate on data structures that are called terms, and a rule engine that interprets rules to transform terms. TuningGenie uses TermWare to extract expert knowledge from program source code and generates a new program version on each tuning iteration. TermWare translates source code into a term and provides transformations according to rewriting rules. The current TermWare version contains components for interaction with Java and C# languages, and the current TuningGenie version supports Java programs.

Application of auto-tuning for complex and nontrivial program systems usually takes a lot of time due to empirical estimating a large number of parameter combinations of input program in a target environment (let us denote the set of parameters combinations as C). In this paper we propose to optimize the auto-tuning method by using statistical modeling and machine learning. The improvement consists in reducing the number of auto-tuner launches by means of building an approximation model which allows dismissing the parameter combinations that are unlikely to be fast. The model approximation often results in a reduction of dimensionality of input parameters of the set C that means significant auto-tuning process speed-up.

Generally, machine learning methods are based on the concept of learning some behavior from data [2, 7]. In the context of auto-tuning, the behavior to be learnt, for example, can be program performance at different settings of program parameters. A machine learning method first evaluates several alternatives within the search space for n different input programs $P_1, \ldots, P_n$, defined by configurations $C_1, \ldots, C_n$. The set of evaluated alternatives is called training data. The process of generating and evaluating the training data and learning behavior from this data is called training. Once the training is completed, and given a new version of program P' to be evaluated, execution of P' is replaced with estimate, obtained from trained model.

Machine learning is closely linked to (and often overlaps with) computational statistics [8]. All statistical algorithms (including machine learning algorithms) require a significant number of statistical data for analysis and model construction. In the context of auto-tuning tasks, the collection of many statistical data can be a long process. Therefore, the problem of selecting the algorithms narrowing the search space at a minimal number of real launches of an auto-tuner is very acute. For a partial solution of the mentioned problem, in this work we use a neural network for data extrapolation (see Section 3). In this case, relatively small number of real launches is required for construction of an approximate model, after which the neural network model can be used by other algorithms according to the black box principle.

3 A Case Study

In the design process, we follow top-down formal transformational style provided by our automated toolkit for designing and synthesis of programs (IDS) [4, 5]. We begin with high-level specification presented as a generalized scheme of the algorithm represented in the algorithmic language of Glushkov's algorithmic algebras [4] that has the advantage to be human-friendly and complete with code in one of the parallel programming languages (Java or C++, in our case).

Below, we consider a case study of performance tuning by the example of a hybrid parallel sorting algorithm which applies a merge sort or an insertion sort depending on a block size (`insertionSortThreshold`) of input numerical array. The initial SAA scheme of the algorithm contains the `tuneAbleParam` pragmas, which specify search domain for optimal values of variables `insertionSortThreshold` and `mergeSortBucketSize`. The resulting algorithm is implemented in Java.

```
"Parallel Hybrid Sorting (arr)"
```

```
==== "Comment(tuneAbleParam name=insertionSortThreshold
              start=10 stop=200 step=10)";
     "Declare a variable (insertionSortThreshold)
      of type (int) with initial value (100)";
     "Comment(tuneAbleParam name=mergeSortBucketSize
              start=5000 stop=1000000 step=5000)";
     "Declare a variable (mergeSortBucketSize)
      of type (int) with initial value (5000)";

     IF 'Length of the array (arr) is less or equal to
          (insertionSortThreshold)'
     THEN "insertionSort(arr)"
     ELSE IF 'Length of the array (arr) is less or equal
              to (mergeSortBucketSize)'
          THEN "sequentialMergeSort(arr)"
          ELSE "concurrentMergeSort(arr)"
          END IF
     END IF
```

In the auto-tuning experiment, the set of 2×10^7 random integer numbers were sorted. The auto-tuner parameters are $C = \{T_{cn}, T_s, T_h\}$, where T_{cn} is a number of parallel threads, T_s is a threshold for block size to be sorted sequentially within the current thread (blocks with $size > T_s$ are split into smaller blocks and assigned to different threads), T_h is a block size at which insertion sort is used.

The experiment was performed in the following environment: 2.7 GHz Intel Core i7 processor (6820HQ) with 4 cores and 8 MB L3 cache; 16 GB 2133 MHz RAM; 512 GB Apple SSD SM0512L; MacOS 10.12.

In a first phase, the auto-tuner was executed without a statistical model to estimate how quick the tuned algorithm can be. In a second phase, the statistical modeling was plugged in to understand how heavily the search space can be pruned while preserving the near-optimum performance of the tuned algorithm.

Let's look at the results of the first phase given in Table 1. Three configurations are listed: *slow* ("default" configuration that behaves almost as classical sequential merge sort); *optimal* (the quickest one that was automatically picked by the auto-tuner) and *intuitive* (values are filled in by intuition with respect to known hardware specifications and algorithms details). *Optimal* configuration is 4.93 times quicker than *slow*. This result is quite good for 4-core processor and was achieved primarily by a combination of two factors: optimal usage of processor caches (by switching to in-place sorting for small data sets) and efficient parallelization schema (merge sort is easy to parallelize with "divide and conquer" method). *Intuitive* combination was 3.1 times faster than *slow* — also a decent result, but it was easy to guess due to relative simplicity of the test algorithm. Usually optimal configurations are not so obvious for real-life parallel programs. *Optimal* configuration is still substantially quicker — by 58%, so we can say that it was worth the time spent on tuning.

Table 1. The results of the first auto-tuning phase.

Configuration	*slow*	*optimal*	*intuitive*
Parallelism level T_{cn}	1 (one thread)	8	4
Insertion sort threshold T_h	0 (do not switch to insertion sort at all)	120	30 (common notion is to set couple dozen as a threshold for this trick)
Threshold for sequential sorting T_s	100 000 000 (it's bigger than the test data size, so no data decomposition is applied)	50 000	10 000
Test data size	20 000 000 integers		
Average sorting time	4432 ms	898 ms	1426 ms

Now let's move to the second phase to see how the auto-tuner's search space can be reduced with the help of statistical analysis methods. T_s parameter is excluded from the model during primary analysis phase because of its minor impact on overall performance: once the number of subtasks after the decomposition of input data is couple times bigger than the parallelism level, it makes almost no difference what value is used. This can be explained by high effectiveness of Java's *RecursiveAction* [9] mechanism that was used in the implementation. *RecursiveAction* is a recursive *ForkJoinTask*, which is "a thread-like entity that is much lighter weight than a normal thread. Huge numbers of tasks and subtasks may be hosted by a small number of actual threads in a ForkJoinPool, at the price of some usage limitations" [10]. The experiment proved that the computational overhead on executing new *RecursiveAction* is negligible.

The primary analysis of data was performed in Python language with a help of Scikit-learn library [11]. Further analysis was implemented by means of R [12], which is a programming language for statistical computations, analysis and graphical representation of data. The experiment consisted of several stages: preparation and loading of auto-tuner results to R environment, data preparation (including normalization), building a neural network model on a training dataset and checking the model on a test dataset.

The data analysis process is shown in Figure 1. At first, the auto-tuner performs N experiments and saves the result data to a separate file. The data is used by the neural network for training. After the training, the neural network extrapolates the data, generates the new dataset, which is written into a separate file. In the end, both datasets are analyzed and compared by a human. As a neural network, a multilayer perceptron with three input neurons, three hidden layers (20-10-5 neurons per layer) and one output neuron were applied. The rectified linear function $f(x) = \max(0, x)$ was used as an activation function. The backward propagation of errors has been used as a machine learning method and the Broyden-Fletcher-Goldfarb-Shanno algorithm [13] has been applied for optimization of weighting factors.

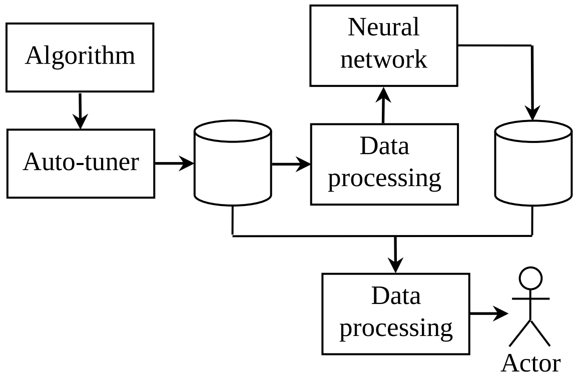

Fig. 1. The process of analysis

The initial neural network was built based on results of 3300 launches. Then it was used for further data generation. The use of the neural network for initial approximation allowed to reduce the search region by 58% (from 10^6 to 4.2×10^5). For estimating the quality of the obtained results, more than 30000 real launches (evenly distributed over the combinations set) of the auto-tuner was performed.

Figure 2 shows the dependency of the model accuracy Acc from 10 neural networks on the ratio of sample data used for training.

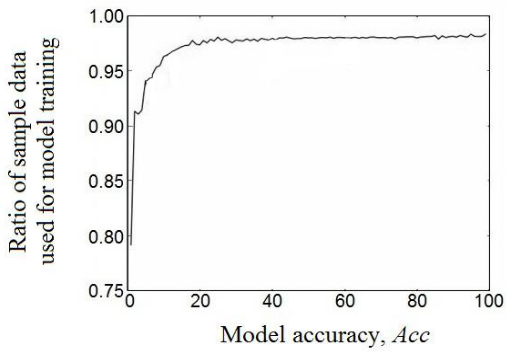

Fig. 2. The dependency of the model accuracy Acc on the ratio of sample data used for model training

The evaluation of the accuracy Acc is based on a confusion matrix [14] and is calculated according to the formula $Acc = \dfrac{TP+TN}{P+N}$, where TP is the number of true positives; TN is the number of true negatives; P is the number of real positive cases in the data; N is the number of real negative cases.

4 Related Work

Many approaches have been proposed for the problem of auto-tuner development. Well-known examples of auto-tuners are ATLAS [15] and FFTW [16], which are specialized libraries introducing high-performance implementation of some specific functions. Unlike our TuningGenie framework, which provides domain independent optimization, they are tied to domain and language. TuningGenie is quite similar to Atune-IL [17], a language extension for auto-tuning. It also uses pragmas and is not tied to some specific programming language. The main difference of TuningGenie is due to term rewriting engine that is used for source code transformation. Representing program code as a term allows modifying program structure in a declarative way. This feature significantly increases the capabilities of the auto-tuning framework.

There are also auto-tuners based on machine learning techniques [2]. In paper [18], an open-source self-tuning compiler Milepost GCC is described, which exploits machine learning to predict optimal setting of compilation flags for a program at using GCC. In [19] neural networks are used to learn the behavior of a given program transformation (parametric loop tiling) for different values of input parameter (tile size); the model is then used to search for optimal parameter values. In the work [20], a machine learning approach is applied for automatic optimization of task partitioning for OpenCL for different input problem sizes and different heterogeneous architectures consisting of CPUs and GPUs. In our work, we use neural networks for learning on the results of tuning cycles (program execution time at different values of internal program parameters) with subsequent replacement of some auto-tuner calls with an evaluation from the model.

Conclusion

In this paper, we explore the promising method of software auto-tuning improved by using statistical modeling and neural networks. The method allows substantially get rid of the main weakness of the auto-tuning methodology, namely, significantly accelerate the search for an optimal program version by automatic training a neural network model on the results of regular tuning cycles and subsequent replacement of some auto-tuner calls with an evaluation from the model. Furthermore, the use of a perceptron at the primary analysis stage helps to identify the most important input parameters (i.e. which have the largest influence on a final result). The approach is illustrated by the example of performance tuning of a hybrid parallel sorting program that exploits the developed earlier TuningGenie framework. The results of the experiment confirmed the efficiency of the proposed approach and the usefulness of its further development, in particular, the use of more complex approximation functions and conducting experiments with more computationally and semantically complex programs.

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Optimization of the Activity of Operators of Critical Systems by Methods of Regulating Operational-Tempo Tension

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Abstract. The model of the influence of the available time on the tension of operators and the infallibility of their activity is considered. The productions and methods of solving possible optimization problems are developed to search for ergonomic reserves to increase the efficiency of critical systems.

Keywords. Critical system, IT resources, ergonomics, poly-ergative system, incident management, human operator, algorithm of activity, operational-tempo tension, self-control, optimization of activities.

1 Introduction

Modern technological, transport, aerospace and energy systems are inherently critical [1,2] because even minor disruptions to their operation can lead to accidents, being catastrophic in most cases. Decision-making processes in critical infrastructures involve the need to process large amounts of information in real time [1,2]. Maintenance of IT resources of critical systems in the effective state and the ensuring their high reliability and efficiency are becoming an increasingly serious problem [1,2].

The analysis of the real operators' activity made it possible to determine the following failure conditions for most cases [3–5]:

- Operational-tempo tension of the activity is the cause of erroneous reactions;
- There are no real mechanisms in place to ensure ergonomic quality, aimed at providing the standards of operator's activity;
- Management of time constraints on the implementation of activity algorithms can be one of the main reserves of increasing ergonomics.

Scientists working within the framework of the functional structural theory of ergotechnical systems of Prof. A.I. Gubinsky, have traditionally paid much attention to the study of optimization problems for operators [6]. Characteristics of some new problems, specific for polyergatic systems, are given in the paper [7]. Unfortunately, despite the huge scientific reserve of that school, in the field of optimization of the human-machine interaction, tasks, as a rule, are solved with the assumption of invariability of the characteristics of the operator in the process of activity and without taking into account the effect of the time resource on the quality of implementation of the algorithms available.

2 Problem Statement

The task is to identify current problems and develop appropriate models that allow solving the problems of optimizing the discrete activity of operators by varying the values of parameters that characterize time resources, i.e. by means of regulation of operational-tempo intensity.

3 Approach

3.1 Models for Managing the Operational-Tempo Tensity

A Model for Assessing the Impact of the Operational-Tempo Tension on the Quality of Activities. Professor P.P. Chabanenko [8] succeeded to identify and formalize the mechanism of the operator's flexible response to the available time resource (based on the study of real engineering and psychological data).

Tension, as a psychological fee for achieving the goal of activity, includes several components, the main ones being the tempo, determined by the time deficit to solve the problem, and the operational one, determined by the nature of the operations of the activity algorithm. The joint operational-tempo tension is determined by the simultaneous influence of two noted factors: The tension H defines the probability P_0 of switching on the self-monitoring of the current operation by the operator [8]:

$$P_0 = -1.836H^2 + 0.962H + 0.874, \quad (1)$$

where H is a ratio of the time required to complete the operation at the maximum rate to the allowable time actually given to the operator to perform this operation.

Optimal tension of the operator's activity: $H_{opt} = 0.262$. The area $H < H_{opt}$ corresponds to an insufficient load on the operator, and the area $H > H_{opt}$ corresponds to an excessive load on the operator.

When $H = H_{opt}$, there is a probability to start a self-monitoring function $P_0 = 1$, which corresponds to the case of setting error-free operation.

When $H = 1$, the probability $P_0 = 0$, which corresponds to the speed setting. An illustration of settings types in the operator's activity is shown in Fig. 1.

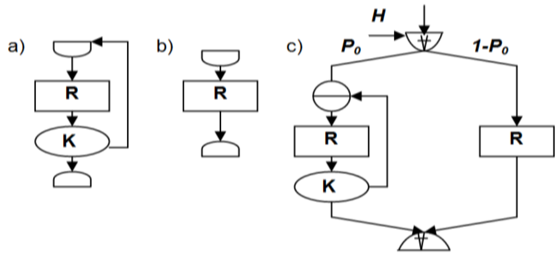

Fig. 1. An illustration of setting types in the operator's activity: a) error-free; b) speed; c) flexible response to the resource of time; R – working operation; K – control operation (notations by [6]).

Models of Activity Optimization by Means of Management of Operational-Tempo Tensity. Time limitations are determined by the characteristics of the flows of incoming signals or orders, or various organizational decisions (including the number of operators in the shift and distribution of functions among them). They may be set instructively by the managing operator or they can be established by software and technical means of activity management.

Depending on the nature of the activity and the level of optimization (function, complex of functions, etc.) we distinguish 2 classes of possible tasks.

Choosing the optimal time constraint for the implementation of activities (1st class of tasks). Task 1.1 (single criterion):

There are given: The structure of the activity algorithm; characteristics of reliability and execution time of operations, permissible time limits for the implementation of the activity algorithm in the form of the lower limit of T_{min} and the upper limit of T_{max} (may not be available); and the maximum permissible activity tensity H_0. It is necessary to choose the limit value T, imposed on the implementation time, which provides the maximum probability of the error-free execution:

$$B(T) \to \max \tag{2}$$

$$H(T) \le H_0 \tag{3}$$

$$T_{\min} \le T \le T_{\max} \tag{4}$$

where T is the allowable time for activity implementation; $B(T)$ is a probability of error-free execution; $H(T)$ is an intensity of the activity; H_0 is a maximum permissible intensity; T_{min}, T_{max} are minimum and maximum times to implement activity.

Task 1.2 (multiple criterion):

The criterion for minimizing the intensity is added to the formulation of the Task 1.1. (2) – (4) instead of, or in addition to the restriction on the intensity (3).

$$H(T) \to \min \tag{5}$$

Task 1.3 (optimization of income from activities):

The statement appears due to the need to solve the problem of the type "what is better: a greater number of implementations of activity algorithm with low infallibility or high infallibility with fewer implementations". The economic consequences of correct (incorrect) implementations of activities can be evaluated in various ways, for example, "income from correct implementation" and "damage from improper implementation".

Consider one of the possible formulations of the problem, taking into account the economic consequences of the activity. The following statements are given in addition to the initial data of tasks 1.1 and 1.2, where C_1 is an income from a single error-free implementation of the activity; C_2 is a damage from a single implementation of the algorithm with an error; $T^{'}$ is a total time during which the activity algorithm should be repeated (taking into account the deduction of time for various breaks: technological, for leisure, etc.). If we consider that the number of applications realized in time is determined by the time allocated for a single implementation $n=T^{'}/T$, the target function will have the form

$$\frac{T'}{T}(C_1 B(T) - C_2(1 - B(T))) \to \max \tag{6}$$

under the constraint (3)-(4).

Task 1.4 (multiple criterion analogue of task 1.3):
The criterion of intensity minimization (5) is added to the statement of task 1.3, instead of, or in addition to the constraint (3).

In the formulations of tasks 1.1-1.4, there is no explicit restriction on the timely implementation of the activity algorithm, since, as follows from the initial assumptions, the activity is pre-configured and the operator provides (at T_{max} not less than the minimum required time for implementation of the activities) timely execution (by enabling or disabling the self-monitoring of operations).

The way to solve the tasks of choosing the optimal time limitations for activity implementation:

Since the analytic dependence for $B(T)$ cannot be defined in principle, and the mathematical model, algorithm and program for calculation of the probability of error-free execution at a given point (for a given T) are developed (see [3–5]), we propose a numerical approach to the solution, based on determining values $T_1, T_2, \ldots, T_s \in [T_{min}, T_{max}]$, the calculation of the criterion function for these values (in case of single criterion optimization) or the "convolution" of the criteria functions (in case of multi criterion optimization) and the values of the indices to which the constraint is imposed (H), and determining the optimal value or search area narrowing (and the repetition of the procedure).

Optimization algorithms based on one-step or multi-step choice are possible. The one-step choice consists of determining the number of points N, calculating values

$$T_i = T_{i-1} + \frac{T_{\max} - T_{\min}}{N}, \tag{7}$$

where $i=1,\ldots,N$, $T_0=T_{min}$, computing $B(T_i)$, $H(T_i)$ (using algorithms and programs [3–5,9,10]) or other criteria functions (depending on the task), and determining the optimal value by a simple search. The disadvantage of the one-step choice is that a large number of points N are needed to ensure high accuracy.

A multi-step search is implemented in a coherent strategy related to the following actions:

1) The use of the selection rule for the first few points $T_1,T_2,\ldots,T_s \in [T_{min},T_{max}]$, and localization of the minimum point on the segment $[T'_{min},T'_{max}]$;

2) Choosing points $T_{S+1},\ldots,T_K$ on the localized segment and determining the next segment;

3) The analysis of the solution that was obtained for an admissible approximation to the optimal one, and the optimal sequential search, carried out by one of the known methods, for example, "Fibonacci search", "Golden section" method, etc.

Distribution of the directive time for realization of activities between their fragments (2nd class of tasks):

Task 2: The statement makes sense in the case when the algorithm of the operator's actions is divided into several parts (fragments): each part is executed in the interval between two events. And the first event (signal) is synchronized with the beginning of the implementation of the algorithm corresponding to the activity fragment, and before the second event (signal) arrives, the algorithm must be completed. Such a situation usually occurs when fragments of system operation algorithms are realized in parallel by a human operator and a machine (with a starter and a functionary of type "AND"[6]).

The fact that it is not always expedient to operate the automation machine with the maximum possible speed is noted in a number of ergonomic studies: For example, in some cases it is recommended to introduce a delay in the "computer response" in order to ensure the comfort of the operator [8].

However, there is no way to determine the optimal reaction time in each particular case. We assume that for technological or economic reasons the maximum permissible time T for the implementation of the algorithm of functioning (AF) of the entire system is set. The task is to determine the directive times for the operator to perform individual fragments performed between the signals of automatic means, ensuring the maximum probability of error-free realization of the entire AF. At the same time, restrictions on the intensity of activity on each of the fragments can be introduced. Here is the definition of vector $(T_1,T_2,\ldots,T_n)$ that provides:

$$F_B(B_1(T_1), B_2(T_2),\ldots, B_n(T_n)) \to \max \tag{8}$$

$$F_T(T_1, T_2,\ldots, T_n) \le T \tag{9}$$

$$H_i(T_i) \le H_i^0, i = 1,\ldots, n \tag{10}$$

where F_B is a dependence of the probability of error-free execution of AF from $B_i(T_i)$, $i=1,\ldots,n$, determined by the structure of AF; T_i is a directive execution time of the i-th fragment of AF; $B_i(T_i)$ is a probability of error-free execution of the i-th fragment of AF; $H_i(T_i)$ is strength of the i-th fragment; H^0_i is maximum permissible tension for the i-th fragment; $F_T(T_1,T_2,\ldots,T_n)$ is a dependence of AF execution time on the execution time of its individual fragments, determined by the structure of AF; n is a number of

AF fragments. F_B and F_T are determined by the models developed for the typical operational structures [3, 10].

In the particular case, when AF fragments are sequentially performed, the statement (7)-(9) takes the form:

$$\prod_{i=1}^{n} B_i(T_i) \to \max \tag{11}$$

$$\sum_{i=1}^{n} T_i \le T \tag{12}$$

$$H_i(T_i) \le H_i^0 \tag{13}$$

The way of solving the task of directive time distribution to realize the activity between their fragments:

Step 1: Generation of a set of directive time values of the fragment implementation for each *i*-th fragment of $i=1,\dots,n$, for example, as follows:

1a. Definition of the range of research $[T^i_{min}, T^i_{max}]$,
where T^i_{min} is the time required to implement the AF fragment without performing functional control for all operations (for example, for a sequential chain of operations,

$$T^i_{\min} = \sum_{j=1}^{n_i} T_{P_{ij}} \ , \tag{14}$$

where n_i is the number of basic work operations in the *i*-th fragment, T_{Pij} is the mathematical expectation of the execution time of the *j*-th operation in the *i*-th fragment);

T^i_{max} is the maximum time value for the AF fragment implementation, provided that all operations are performed with self-monitoring and taking into account the variance of the execution time, for example, for a sequential chain of operations

$$T^i_{\max} = \sum_{j=1}^{n_i} T_{PK_{ij}} + 3\Big(\sum_{j=1}^{n_i} D_{PK_{ij}}\Big)^{1/2} , \tag{15}$$

where T_{PKij} and D_{PKij} are the mathematical expectation and a variance of the execution time in the *i*-th fragment of AF of the *j*-th self-monitoring operation.

1b. Definition of the number of investigated values of the directive execution time N_i for each *i*-th fragment $i=1,\dots,n$, and generation of the following values: $T_{i,1}, T_{i,2}, \dots, T_{i,Ni} \in [T^i_{min}, T^i_{max}]$, in the simplest case

$$T_{i,k} = T_{i,k-1} + \frac{T^i_{\max} - T^i_{\min}}{N_i} , \tag{16}$$

where $i=1,\dots,n$ and $T_{i,0}=T^i_{min}$.

Step 2. Evaluation of error-free and activity intensity values on each i-th fragment, $i=1,\ldots,n$, with all the generated values of the directive time: $B_i(T_{i,j})$, $H_i(T_{i,j})$, $i=1,\ldots,n$, and $j=1,\ldots,N_i$. The evaluation is carried out by using models and programs developed in [3–5, 9 and 10].

Step 3. An exception for each i-th activity fragment of $Ti,j(i=1,\ldots,n, j=1,\ldots,N_i)$ those values that do not satisfy the constraints on the activity tensity $H_i(T_{i,j})\leq H^0{}_i$.

Step 4. Choosing the best option. With the generated variants of the execution of fragments with available estimates of the quality indicators, the task is reduced to the standard problem of maximizing the probability of error-free execution of AF under the constraint on the mathematical expectation of the execution time [6,7 and 10].

Step 5. Investigation of the vector obtained as a result of the solution of the optimization problem. $(T^*{}_1,T^*{}_2,\ldots,T^*{}_n)$; generation of directive time values for each i-th fragment in the range $[T^*{}_i-\Delta_i, T^*{}_i+\Delta_i]$, ($\Delta_i$ can be determined, for example

$$\Delta_i = \frac{T^i_{\max} - T^i_{\min}}{N_i} \tag{17}$$

(see 1b)), and transition to step 2 (steps 2-5 should be repeated until the solution with required accuracy is obtained).

The convenience of the approach is that one of the steps reduces the task to the known problem of optimizing a human machine system and can be solved by any known method [6,7, 9,10] with any structure of connections between operations.

4 Applications

The models were used in the development of the following systems ensuring ergonomic quality:

- Automated processing plants for various purposes [3];
- Systems of technical support of IT resources in telecommunications [9,10];
- Distributed banking processing systems [4];
- Relevant topics of the training courses on "Ergonomics" and "Information Systems" at the Sumy State University, the Sumy National Agrarian University and the National University of Bio-Resources and Nature Management (Kyiv).

5 Conclusion

Operational-tempo tension is determined by time constraints on the activity of operators of critical systems and significantly affects the indicators of error-free functioning. It is convenient to evaluate the influence of time resources on the efficiency of ergotechnical systems by using models based on formalisms introduced by Prof. P.P. Chabanenko.

Solving the tasks of choosing temporal constraints for the implementation of activities and the distribution of directive time for the execution of work between its fragments makes it possible to ensure the fulfillment of specified requirements for the operation of critical systems while observing the normative indicators of the intensity of the operators' activities. Solving the problems of choosing a temporary restriction on the implementation of activities and the distribution of directive time for the implementation of activities between its fragments can provide specified requirements for the effectiveness of critical systems, while observing the normative values of the activity intensity of operators.

The models should be used as elements of mathematical support of DSS for operators-managers of critical systems.

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The Construction of the Algorithm Study Based on the Mathematical Model of Motion

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Abstract. The purpose of this work is the construction of the algorithm study a neural network based on the mathematical model of the motion in remotely piloted aircraft systems (RPAS) or unmanned vehicle aircraft (UAV). Information technologies are considered in the UAV control system to provide two-way information transfer between the on-board computer UAV and the operator.
The problem arises in the analysis of big amounts of data with information which come from the operator to the on-board computer and in the opposite direction, as well as with a constant change under the influence of external factors. In case of distorted data transmission or collision with obstacles a hang-up and drop of the UAV is possible.
Taking into account the rapid growth of UAV usage for civilian and military purposes, the neural network training algorithm for processing the input signal is offered. It can facilitate the task of data analysis and reduce the likelihood of uncertain situations. This algorithm is designed to predict the development of the situation, increase accuracy, the rate of information transfer and its reliability.

Keywords: unmanned aerial vehicle, information technology, data transmission, algorithm study, big amounts of data.

1 Introduction

To build the neural network of the algorithm study for two-way information transfer, it is necessary to collect and prepare data for training; determine the parameters of the model for training; implement the model in the form of program code; train the model on the collected data; test the model.

The RPAS or UAV includes its own control system, which usually also contains an engine. The control system solves the problem of controlling a particular engine in order to achieve the given values of the generalized coordinates. The task for controlling the engines is to bring the BTS to the trajectory control level, where the task of calculating the generalized coordinates and selecting the trajectory for achieving the specified position or position is solved.

1.1 Data Collection

The main stage in the construction the algorithm of study is the collection and preparation of data for learning the model. Required data for the collection, storage and processing of information between the operator and the on-board computer of the UAV - the altitude, latitude, longitude and turns in the Euclidean coordinate system relative to the UAV coordinate system, known as Euler angles: pitch, roll and yaw.

Preliminary processing of the data usually improves the results, so it is worth deleting obviously wrong combinations. After that, the information is divided into parts (height, angles of rotation, coordinate values). Next, a dictionary is created, the data is transferred to key arrays, which will be the input data for the information transfer model (dialog model).

2 Theoretical Basics

2.1 Dialog Model

In this work, the Sequence-to-Sequence dialog model, proposed by Google, is implemented, which is successfully used in the task of machine translation. Training takes place with the teacher, the input is given a sequence of tokens (the phrase in the original language), output too (translation) [1].

This model can also be used for information transfer (dialog model). The difference is that instead of translating from one language to another, one language is used. The question and answers should be the same, the axis is the time axis.

2.2 The Algorithm of Study

In this work, the algorithm of study the recurrent neural network Long short-term memory (LSTM) is implemented [2] (see Fig. 1).

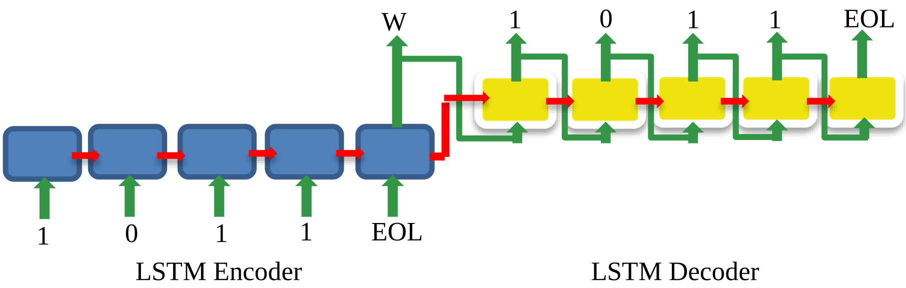

Fig. 1. Neural Network Architecture

Long Short Term Memory networks – usually just called “LSTMs” – are a special kind of Recurrent Neural Networks (RNN), capable of learning long-term dependencies. They were introduced by Hochreiter & Schmidhuber (1997), and were refined and popularized by many people in following work [3].

LSTMs are explicitly designed to avoid the long-term dependency problem. Remembering information for long periods of time is practically their default behavior, not something they struggle to learn.

Other attempts to avoid the long-term dependency problem include the use of powerful second order optimization algorithms [4][5], regularization of the RNN's weights that ensures that the long-term dependency does not vanish [6], giving up on studying the recurrent weights altogether [7][8] and a very careful initialization of RNN's parameters [9].

All recurrent neural networks have the form of a chain of repeating modules of neural network. In standard RNNs, this repeating module will have a very simple structure, such as a single tanh layer (hyperbolic tangent).

LSTMs also have this chain like structure, but the repeating module has a different structure. Instead of having a single neural network layer, there are four, interacting in a very special way.

The main feature of recurrent networks in comparison with traditional ones is the presence of feedbacks, by means of which signals, which are some sequence, from the outputs of these neurons are fed to their inputs. The values of the sequence are transmitted along with the predictions until the sequence ends.

Unlike simple recurrent networks, LSTM has three filters (input, output, forget), with which the signal is controlled inside a neuron [10] (see Fig. 2).

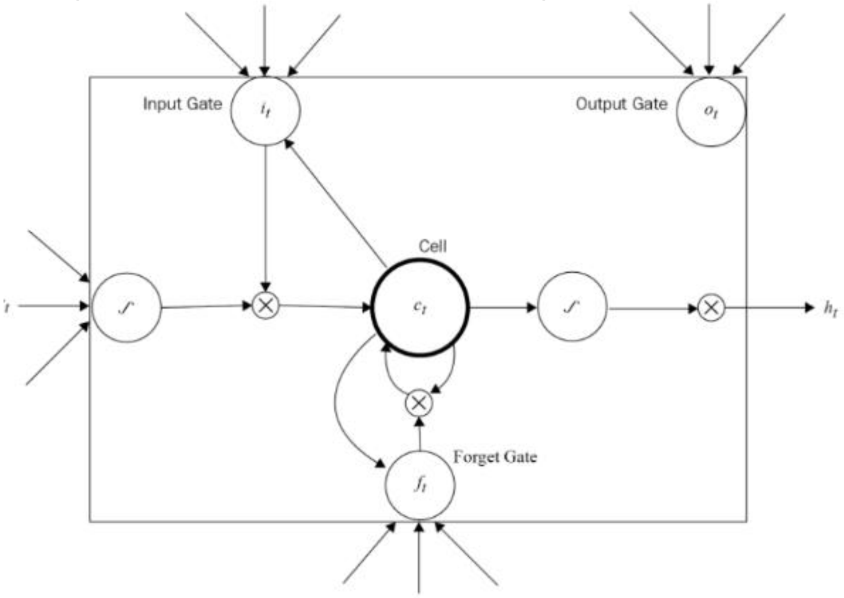

Fig. 2. Long Short Term Memory neuron

3 Using LSTM for the Construction of the Algorithm Study

The parameters of the signal include the accuracy and speed of information transfer. By processing the input signal properly, you can significantly simplify the task of analyzing information, its accuracy, rate and reliability of transmission. Manually adjusting the signal parameters when changing the characteristics of information in time, requires a lot of time. Therefore, for signal processing, its analysis depends on the influence of external factors, the signal must first be processed. One of the approaches to solving this problem is the construction of an expert model and algorithms for the logical derivation of solutions using certain methods of adjusting the signal parameters [11].

Another approach is the implementation of the neural network training algorithm to provide reliable two-way information transfer between the on-board computer of the UAV and the operator.

3.1 Mathematically

Let's describe the LSTM additions mathematically. At time t, we receive a new input x_t. We also have our long-term and working memories passed on from the previous time step, ltm_t-1 and wm_{t-1} (both n-length vectors), which we want to update.

We'll start with our long-term memory. First, we need to know which pieces of long-term memory to continue remembering and which to discard, so we want to use the new input and our working memory to learn a remember gate of n numbers between 0 and 1, each of which determines how much of a long-term memory element to keep. (1 means to keep it, 0 means to forget it entirely).

We can use a small neural network to learn this remember gate.

$$remember_t = \sigma(W_r x_t + U_r wm_{t-1}) \qquad (1)$$

Next, we need to compute the information we can learn from x_t, i.e., a candidate addition to our long-term memory.

$$ltm'_t = \phi(W_l x_t + U_l wm_{t-1}), \qquad (2)$$

ϕ is an activation function, commonly chosen to be *tanh*.

Before we add the candidate into our memory, though, we want to learn which parts of it are actually worth using and saving.

$$save_t = \sigma(W_s x_t + U_s wm_{t-1}) \qquad (3)$$

Combine all these steps. After forgetting memories we don't think we'll ever need again and saving useful pieces of incoming information, we have our updated long-term memory.

$$ltm_t = remember_t \circ ltm_{t-1} + save_t \circ ltm'_t, \qquad (2)$$

where ∘ denotes element-wise multiplication.

Next, let's update our working memory. We want to learn how to focus our long-term memory into information that will be immediately useful. Let’s study a focus/attention vector.

$$focus_t=\sigma(W_f x_t+U_f wm_{t-1}) \tag{5}$$

Our working memory is then:

$$wm_t = focus_t \circ \phi(ltm_t) \tag{6}$$

In other words, we pay full attention to elements where the focus is 1, and ignore elements where the focus is 0.

3.2 Structure of the Software

For realization in the information storage unit, a matrix of values of the required quantities is created depending on the time. The values for storage are: height, latitude, longitude, pitch, roll and yaw, the time period is set to 1, 2 and 3 seconds.

Table 1. Matrix in the information storage unit

	height	latitude	longitude	pitch	roll	yaw
1 sec	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
2 sec	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}
3 sec	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}

The result of the operation of the information analysis algorithms and the neural network training algorithm depends directly on the input data. I.e. from the signal, which corresponds to the exact parameters.

As a neural network, there are 100 cells LSTM.

The received information is broken by element, and we learn the recurrent neural network to predict the next bit of information based on the previous bits.

Having learned a neural network, we can perform predictions of the next chain in this way.

We select the initial symbol. You can take just anyone with equal probability, or consider the probability of the appearance of symbols in the transmission / receipt. Either take the frequencies of the initial transmission symbol.

Then, in the loop, take the previously selected symbol and skip it through RNN, obtaining the output vector of the forecast.

The output layer works by softmax activation, so that the predicted neural network forecasts correspond to the probability of appearance of characters from the set.

We generate a random number [0,1) and choose a symbol according to these probabilities. Add the selected symbol to the chain and repeat the procedure a number of times.

To improve the code, each sentence on which RNN is learning is framed by two special characters <begin> and <end>.

To start generating a new sentence, it is enough to apply a token <start> to the input of the neural network. And the neural network itself knows which symbols usually come first. Also, if the choice on the next step falls on the symbol <end>, then we interrupt. This provides a more beautiful ending for the sequences being created.

For development, the Google Tensorflow library [12] was used. The function that initializes the Sequence-to-Sequence model is shown below:

```
decoderOutputs, states =
tf.contrib.legacy_seq2seq.embedding_attention_seq2seq(
      self.encoderInputs,
      self.decoderInputs,
      encoDecoCell,
      self.textData.getVocabularySize(),
      self.textData.getVocabularySize(),
      embedding_size=self.args.embeddingSize,
      output_projection=outputProjection.getWeights()
      if outputProjection else None,
      feed_previous=bool(self.args.test) )
```

The LSTM cell creation code is:

```
def create_rnn_cell():
      encoDecoCell = tf.contrib.rnn.BasicLSTMCell(
          self.args.hiddenSize,
      )
      if not self.args.test:
          encoDecoCell = tf.contrib.rnn.DropoutWrapper(
              encoDecoCell,
              input_keep_prob=1.0,
              output_keep_prob=self.args.dropout
          )
      return encoDecoCell
```

self.encoderInputs - list of the number of neurons on the hidden layer.

self.decoderInputs - a list with the same length as self.encoderInputs, but it is used as a decoder in the sequence2sequence model.

self.textData.getVocabularySize () - the number of unique tokens.

self.args.embeddingSize - the dimension of each sequence.

encoDecoCell - cell type (neuron), maybe both LSTM, and GRU.

tf.contrib.rnn.DropoutWrapper - during the network training, the random part of the neurons does not participate in the prediction, which allows the model not to retrain.

Symbols of the beginning and the end of the chain are added by hand, since they are not in the library explicitly.

chars_set.add('\r')

chars_set.add('\n')

Parameters for creating this model:
- maximum sequence length - 20 conversations;
- number of hidden layers - 6;
- the number of neurons on each hidden layer is 64;
- the number of examples that must pass through the network before updating the scale - 32;
- number of epochs – 20.

3.3 Training Model

Training recurrent neural with the help of the CPU requires a lot of resources and, as a consequence, takes a long time. Therefore, the training of the model will be conducted on the cloud service. For example, from the company Amazon [13]. With its help, the training of such a model of a long 20 it is possible to train in 10-15 seconds for an epoch.

3.4 Results

The model was tested on similar data during signal transmission.

Data for training was taken on 100 cells of the LSTM model, which is not enough, and the model constructed did not always correspond correctly, the prediction algorithm was not always accurate.

For example, in order to obtain reliable results, more than 1 million dialogues were used in problem [14].

4 Conclusions

This work describes the construction of an algorithm based on the mathematical model of UAV motion, the process of collecting data for constructing an algorithm. It describes the approach to the implementation and training of the dialogue model using the LSTM network, the basic principles of the work of recurrent neural networks. A mathematical description is given and a program is written for using LSTM to build the learning algorithm.

The structure of the long-term memory of the neural network is developed.

An algorithm for training the neural network is proposed to provide reliable two-way information transfer between the on-board computer of the UAV and the operator.

An algorithm for working with the determination of the probability of the appearance of symbols in the transmission/receipt is given.

The constructed matrix for the information storage unit. As a neural network, 100 LSTM cells are taken. The main parameters for creating such an algorithm of training based on the mathematical model of motion for UAV are described.

The Google Tensorflow library was used for development.

To improve the results of the dialogue model it is necessary to collect more data, apply word2vec technology for data preparation [15], optimize the model parameters (number of layers, number of neurons).

In the future, scientific research should be directed at increasing the speed of information processing.

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The Neuromarketing ICT Technique for Assessing Buyer Emotional Fatigue

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Abstract. Typical consumer receives steady stream of information at purchase process. In the process of perception of this information he must not only find necessary data for him, but also process, analyses it, evaluate and weigh the pros and cons, relate it to his own needs, and at the end to make a decision: to buy or not to buy certain product. All named factors cause consumer's fatigue, stress and even aggression. In this case, the buyer can make the wrong choice and the quality of his decisions would deteriorate and it is difficult to make a decision about the purchase in such conditions.
The research is aimed at assessing the impact of the elements of the process of purchases on the emotional state of the buyer in the urban retailer. The method to assess the emotional fatigue using galvanic skin reaction (GSR) and hart rate (HR) has been presented. The elements of purchase process and stimuli affecting the buyer were assessed to find overall fatigue in current shop visiting.

Keywords. customer, emotion, state, ICT, GSR, BPM

1 Introduction

The phenomenon of consumer emotional fatigue is not new, but it is still not enough considered. It has been examined and described using the example of car selling [1]; design-making process on prices, promotions and impulse buying [2]. Changes in consumers' emotional state at different time of the day describe by Chebat, Dubé, & Marquis [3] and Kerkhof [4]. Researches, in presented studies, are comparing human reaction (using experimental method) with simultaneous answers to questions about his/her feelings (using questionnaires) during the core processes. Noseworthy, Di Muro and Murray [5] in their research asked participants to indicate their level of excitement at a certain scale, with numerical values: «a very relaxed state», «very excited state» and «not relaxed, not excited». After the action of a stimulus, the participants need to stop the movement of the slider at the level corresponding to their senses [6]. Subjects' emotional state can measure using the Pleasure-Arousal-Dominance scale also [3]. Other approaches assess the human response to fear, pain, laughter, pleasant and unpleasant sense, anger, joy, sadness, etc., with the help of displaying images and videos. After the action of a stimulus the pause is made and the reaction of the human body is checked. The tested person also indicates what she/he reacts to different stimulus [7], stress evolution data [8].

These examples describe «simple» human reactions and allow to get the results of experiments in a «pure» form, when the action of environmental factors on the tested person is reduced to a minimum. This, on the one hand, allows determining maximally correctly the emotion of the person based on the results of his responses and instrument indications. But at the same time, in everyday life, there are no experiments in pure form. The environment constantly affects the person's behaviour and emotional state. It is therefore important to understand how the buyer will behave under the influence of specific environment at retailer. Consequently, only experimental data obtained in real conditions will be able to describe, identify and understand to the full extent what the person feels at one or another point of purchasing process. However, consumer researchers have never been able to record the internal emotional fatigue processes in directly real purchase process. It's always been limited to designing experiments. We conducted several real-time purchase experiments which give opportunity to make particular conclusions depending on the real environment. Research proves influence of purchase process and different stimuli in it on the buyer's emotional state and his/her fatigue appearance during any shopping, using of skin galvanic respond and pulse meter equipment.

An equally important question is the study of the different elements of the urban purchase process (problem recognition, information search, alternative evaluation, decision about purchase, behavior after purchase), their impact on emotional state of buyer and demand in a particular store.

The aim of the research is to study the emotional state of the buyer from different elements of purchases process. Therefore, the specific objectives of this paper are:

1) to develop a method for assessing the emotional state of the buyer.

2) to conduct experiments on different people who visit different retailers and evaluate their emotional state during different elements of urban purchase process.

2 System "Buyer – Retailer – Resource Management System – Environment"

Consumer behavior is complex person reaction to a set of conditions forming his motivation for the purchase objectives, time, place of purchase, sales, and services, which is often unpredictable. It is directly related to the acquisition and consumption of goods and services, with the order of them, including the decision-making processes that precede these actions and follow them.

The purchases process is interacting a few systems: marketing (product, price, promotion and place), environment (economy, technology, politics, demography, nature), competitive environment (other retailers, their distance from the consumer, size range, goods substitutes etc.) and person – buyer. Specific features and problems arising during purchases, can be caused as well by the system: “person – tool – work place – industrial environment” [9]. Designing and functioning of the system “The buyer – Retailer – Recourse Management system – The environment” (BRME) is connected with the TS efficiency increase for the society, in general, at purchasing.

Studying of factors affecting it requires new approaches and methods of the evaluation which will help to increase sales, on the one hand, and to raise the shop’s efficiency functioning, and from other – to diminish buyers' fatigue and to increase benefits from purchases exactly in particular retailer or retail network.

In the modern conditions person interacts with various social, economic, biological systems in which he lives, works and rests [10]. One of such systems is the system of consumption of goods, essential component of which is a process of purchases. To the elements of the system of the purchases process consist of: buyer, shop, environment, and control system (BRME), fig. 1.

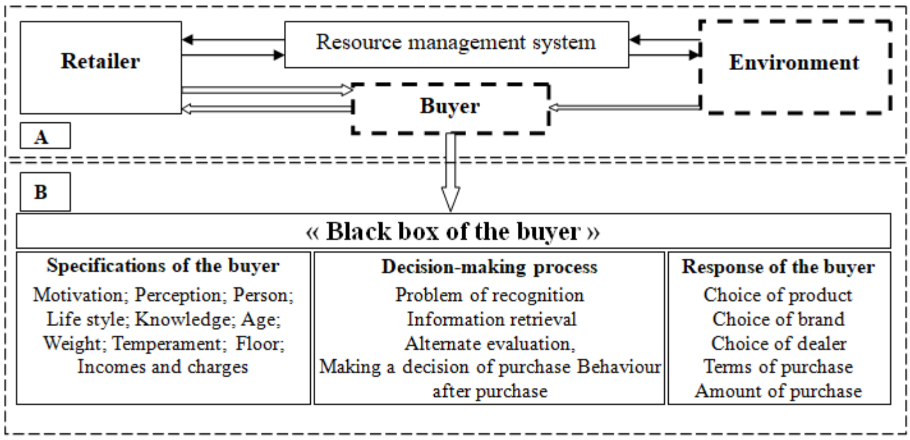


Fig. 1. Interrelation of the elements of the system “BRME” (A) and “Buyer” (B)

The buyer’s emotional fatigue can be assessing according to BRME system, taking into account other elements interaction. Complex and system approach provide retailer’s tool for competitiveness and stimulating the purchase process which would take into account consumers' behavior.

3 Method Statement

There is no doubt that human body has created any special reaction in purchase process of visiting certain retailer. Walk for long distance, «clamming» up the hill or heavy traffic on intersaction act as a stimulus and influence on buyer's emotional state and his fatigue on way to shop and back. Conveniences inside of the shops, layout of goods, the amount of open cash desks, non-stressful atmosphere, polite and helpful staffs make their impact on emotional fatigue of buyer during searching and selecting of goods, and making purchase decision (fig. 2). A different retailer creates various stimuli for buyer. Buyer's reaction on it could be assumes in different stages using Pulse meter for fatigue measurements and GSR – for arousal emotions and fatigue. We measured reaction on stimulus at whole purchase process.

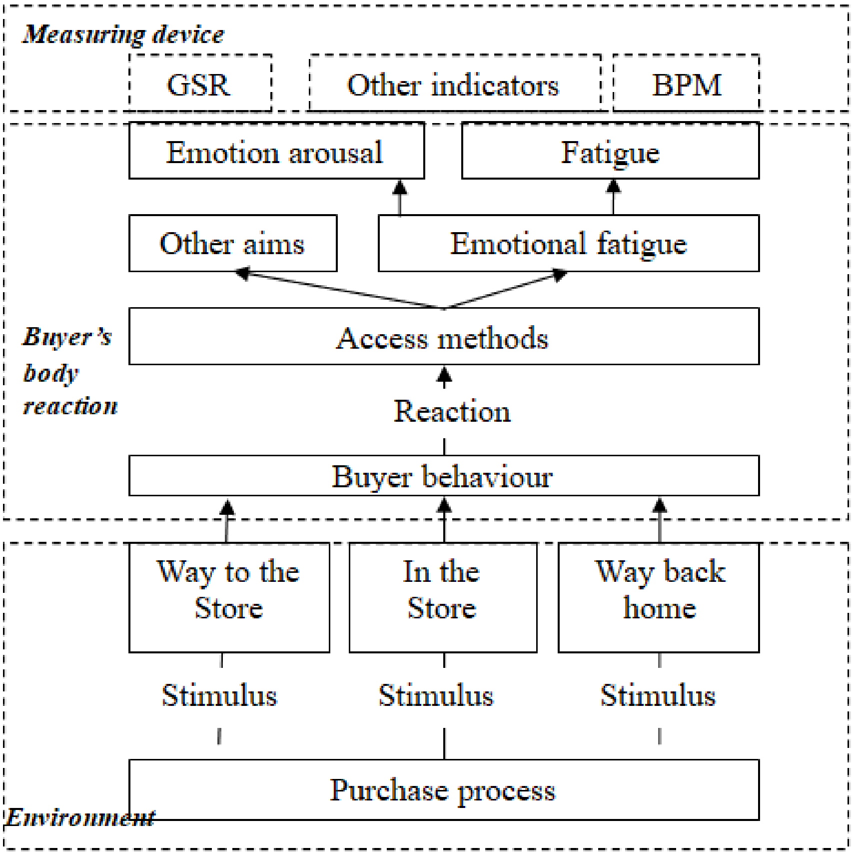


Fig. 2. Conceptual framework of emotional fatigue research

Therefore, we suggest that any of these actions or things in purchase process could be stimulus for consumer's emotional reaction. Here, we explore, how human organism (semantic system, circulatory system, nervous system) reacting on purchase process elements in different stores according to stress-index and emotional shift level.
For understanding changing of emotional fatigue was used shift of level of buyer's emotional reaction [11] as emotional component and stress-index [12] as fatigue component [13]. Measurement was made at start of element of purchase process and at the end of it. The shift between measurements indicates about emotional fatigue of

buyer at current element. Also, interests are reaction on the rapid stimuli: pick of need product, standing in line before cashier, moment of making purchase, cell rang and other. It was asses by shift of GSR value.

Also, were compared current human biometrics performances (moda of R-R intervals, amplitude of a mode, R-R variation scope) with normal state. According to this, assess of body state has been made.

To assess buyer’s background emotional fatigue during purchase process was made sample before exit from home (GSR value) and compare with end state value – after coming back. The change between two values indicates about increase of buyer’s background emotional fatigue level.

4 The Results of the Conducted Experiment

Assessment of the impact of the process of purchases on the functional state of person was held by fixing the body's response to the different factors with the help of galvanic skin reaction and heart rate. The following factors in the shopping process were studied: time spent on the walking to the retailer and back; time spent in a store; the process of selection and evaluation of products; the decision to purchase; waiting in line before the cashier; moment of making purchase. It is established that if the store is placed within a long walking distance then additional factors must be taken into account: time spent on the getting to the transport stop and back; time spent waiting at the transport stop; change of the types of transport; time spent in transport.

The most informative parameters of the influence of information flow on the behaviour of the buyer were selected for this study. They are identified with the help of measurement of G.S.R. cardiovascular rhythm. G.S.R. sensor was attached on the left hand on the index and ring fingers. NeuLog Pulse sensor was attached to the little finger of the left hand, (Fig. 3).

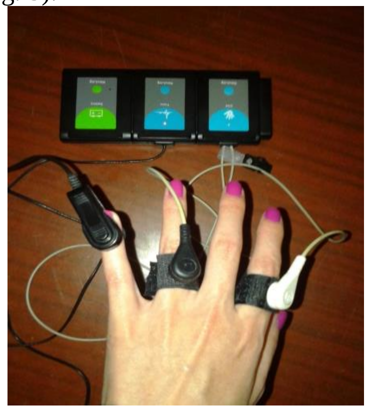


Fig. 2. Mounting sensors on the buyer

Routes of the experiments are presented at the Fig. 4.

a) b)

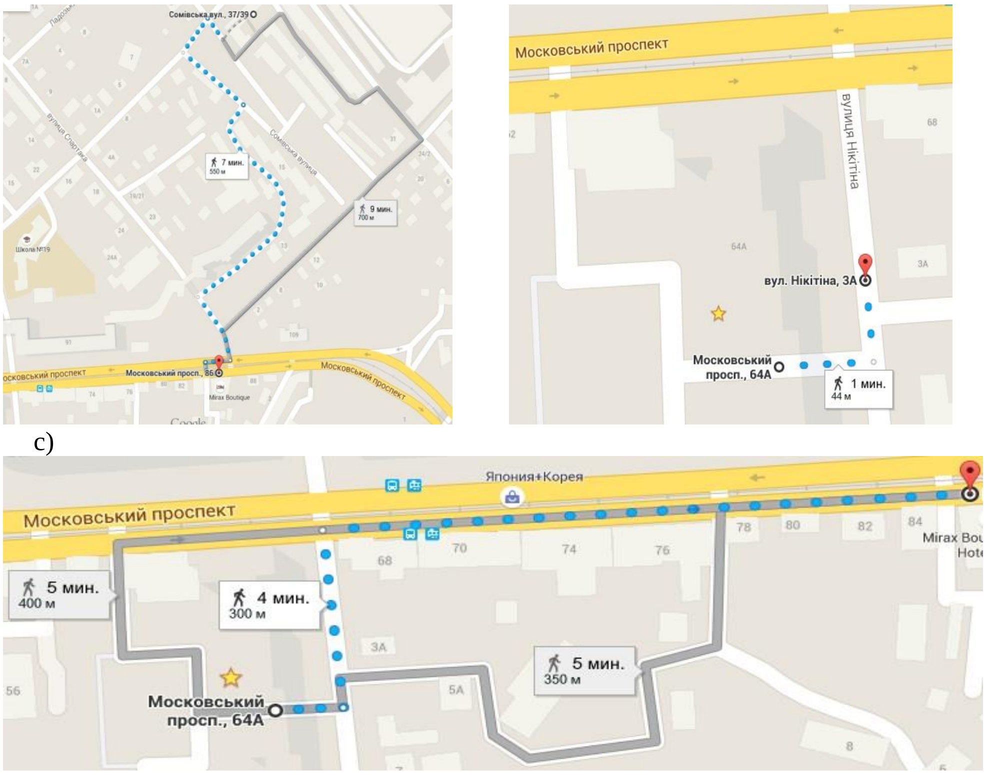


Fig. 3. Routes of the experiments

Along with the registration of G.S.R. in the store and on the way to it photo and video fixation of the buyer's behaviour was conducted (Fig. 5).

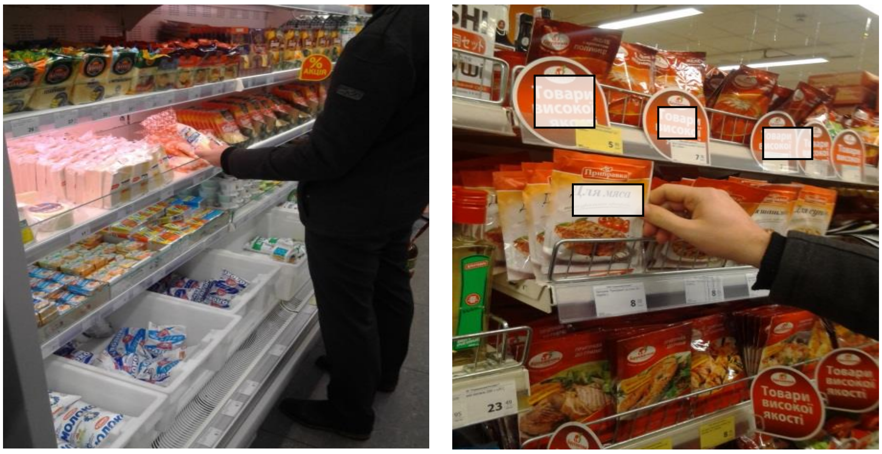
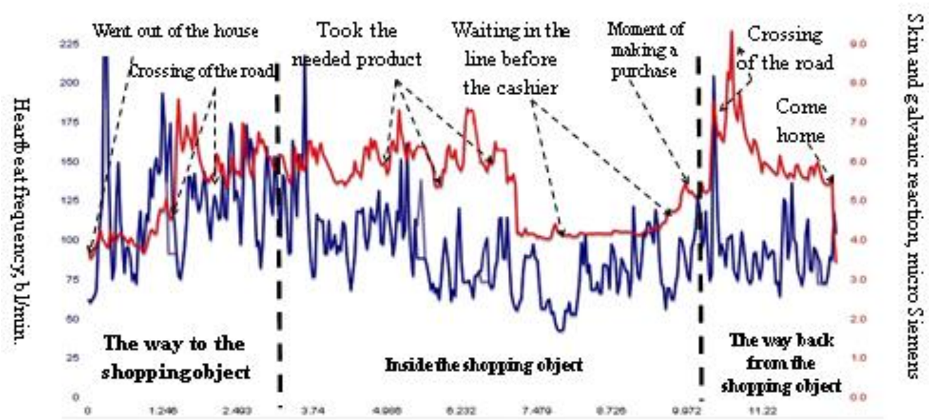


Fig. 5. Example of the photo and video fixation of the experiment

Overlaying of the video on the measurements of sensors made it possible to determine what the tested person felt at different moments of purchasing. This process was done by hand. For the convenience recording was started synchronously with the start of sensors work (fig. 6-8).



Time, minutes.

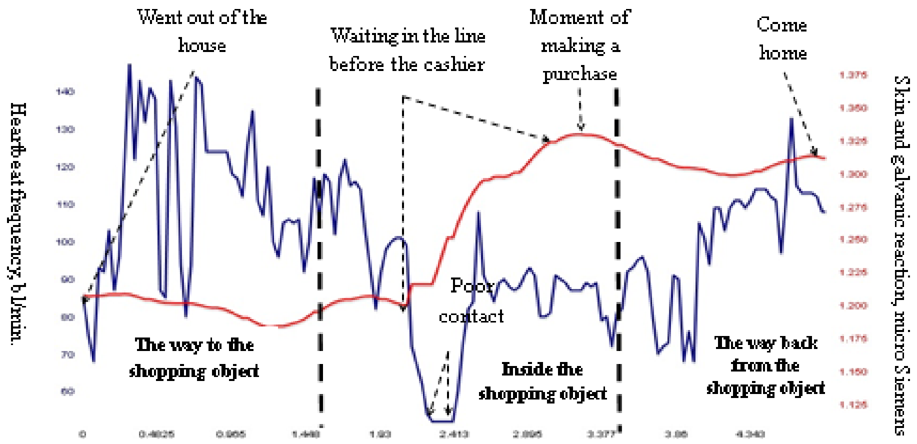
Fig. 6. Measurement of the G.S.R. (microsiemens) and pulse (beats per minute) of the buyer during visit of the retailer which is located at a distance of 550 meters from his home area. The square of the retailer is 450 m^2; number of purchases – three; gender – male; frequency of measurements is 6 times per second (Fig. 4 a)

It should be noted that the average heart rate and GSR reaction per minute data show its value in chosen activity when the frequency of measurement is 6 times per second.

Value of one purchase did not exceed 200 hryvnyas (8 USD), the average amount was 75 hryvnyas (3 USD). All shops were within walking distance. The visited shops were the following: small shops, discounters, stores near the house.

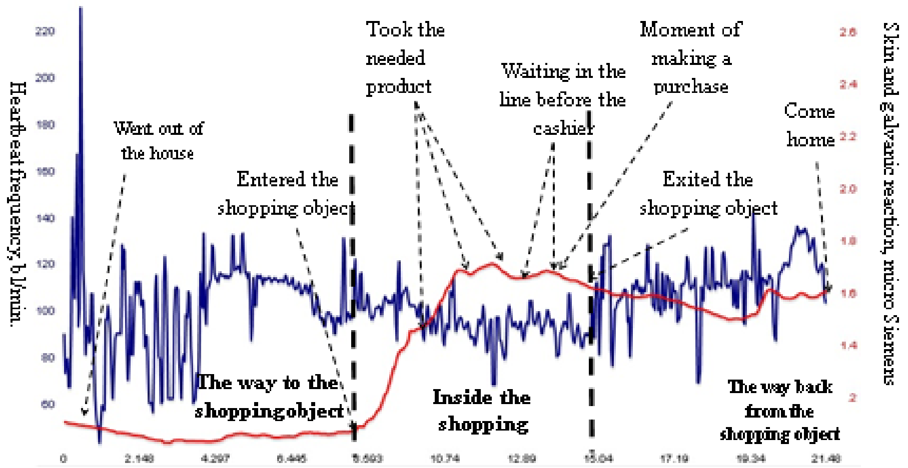
The results of measurements of «NEULOG» show that the buyer suffers less tension on the street on his way to the retailer than in the shop. It should be noted that at all pictures, the buyer's stress state increases in the moment of transition the road (roadway), as evidenced by his G.S.R. and heart rate rhythms.

The results showed an ambiguous character in determining of the heart rate rhythm. Thus, in Fig. 6, 8 heart rate rhythm in the moments of leaving home and returning home has not changed or even decreased. In all other cases, heart rate increased after returning home. Ambiguous results of the data require further studies with more people.



Time, minutes.

Fig. 7. Change of the G.S.R. (microsiemens) and pulse (beats per minute) of the buyer during visit of the retailer which is located at a distance of 50 meters from his home area. The square of the retailer is 20 m^2; number of purchases – one; gender – female; frequency of measurements is 6 times per second (Fig. 4 b)



Time, minutes.

Fig. 8. Change of the G.S.R. (microsiemens) and pulse (beats per minute) of the buyer during visit of the retailer which is located at a distance of 300 meters from his home area. The square of the retailer is 450 m^2; number of purchases – three; gender – female; frequency of measurements is 6 times per second (Fig. 4 c)

Analysis of the experiments showed that the bigger is the galvanic skin reaction of the person when coming out of the house before buying, the bigger this index will be when he returns home, which makes it an essential parameter.

It is established that influence of the duration of the process of purchases on adaptive properties of the human body is negative. The longer buyer walks in the store, the more tired he becomes and his stressful condition is bigger also, he can not make purchases and choose needed things. The indications of G.S.R. demonstrate it very good in the moments of leaving home and getting back home. The amplitude of changes varies from 0.25 microsiemens (for 5 minutes) till 2.5 microsiemens (for 15 min.). A similar conclusion can be made from the analysis of heart rate rhythm. Duration of the shopping process increases the frequency and amplitude of heart rate rhythm that is clearly visible at Fig. 6.

If we consider the waiting time in the line before the cashier, the change of the G.S.R. almost does not occur, and the heart rate rhythm changes (Fig. 6, 8). Heart rate indicator shows that a person is in the calm state, the range of the heart rate varies from 80 to 100 beats per minute. Before making a purchase, the variation range increases to 70-120 beats per min.

A detailed analysis of the elements of measurement of G.S.R. (Fig. 6-8) shows that the increase of the voltage depends on the conditions for purchases (environment), on the person and on the shopping object.

5 Analysing the Results of Urban Purchase Process

Change of the parameters (G.S.R., BPM) depends on the initial indicator of the state of the person in the moment of leaving the house. The higher it is, the stronger is the buyer's reaction to shopping. Gyulyev & Dolia [14] noted in their researches that the ultimate fatigue of the passenger depends on the first measurement before when he leaves his home.

With the different figures, it can be observed that signals increase or decrease depending on the purchase process elements and buyer's parameters (gender, age, etc.). Different people react differently to stimuli in the process of shopping. It is believed that the long wait in line has a negative impact on the emotional state of a person and his tiredness [15]. Fig. 6, 8, show that waiting in the line for more than 2 minutes had virtually no impact on the buyer. Just before the cashier it is observed a slight increase of the G.S.R., caused by the fact that he is laying out the goods at the checkout. At the same time the data of fig. 6 indicate that even the short time of waiting in the line (1.5 min.) negatively affects the emotional state of the person: G.S.R. is increased sharply at 0.5 points; heart rate is jumping. Perhaps the difference in the emotional reaction of different people depends on the type of their temperament [16]. Anyway, it is necessary to increase the data sampling and conduct appropriate tests to determine the temperament of the people who take part in the investigation.

6 Discussion

Already existing studies and methods compare human reaction (using experimental method) with simultaneous answers to questions about his/her feelings (using questionnaires) during core processes.

Main part of the research is devoted to the analysis of the factors that affect the buyer and measuring of his G.S.R. and heart rate indicators during the shopping process. The combination of multiple signals helps assess the buyer's reaction to stimuli in a better way [17]. The environment constantly affects the person's behaviour and emotional state. Therefore important to understand how the buyer will behave under the influence of specific environment at the retailer at him/her. How will the location of the goods on the shelves and departments in the store affect the results of his choice and fatigue? What feelings will call advertising at the entrance to the commercial property? How the lines before the cashier and the amount of opened cashboxes will affect him? How will the other elements of the trading service affect his emotional state, behaviour, and the result of purchases? All these questions are difficult to answer unequivocally only in laboratory conditions. Consequently, only experimental data obtained in real conditions will be able to describe, identify and understand to the full extent what the person feels at one or another point of purchasing process. Implementation of BRME system approach can help answer to this issues.

7 Conclusion

The conducted research, at first time, has estimated the buyer's emotional state and allowed quantifying objective response of the buyer’s body in the process of making purchases. Assessment of the impact of various factors was measured by the galvanic skin reaction and heart beats per minute. It is revealed that people's reaction in the shopping centres can be measured with the help of medical devices. The study has shown the changing parameters of the galvanic skin reaction and frequency of cardiovascular rhythm depending on duration of purchases and the number of roads «on the way to» and «back» from the retailer, at retailer, the correct choice of goods, waiting in line before the cashier. The results of the study can be used for planning sales areas, shops, sales analysis, advertising campaigns and analysis of the customer’s behaviour.

Usage of this method can help to estimate the level of emotional fatigue of the buyer during its visit to any shopping object. Also, shopping object affects emotional state on the buyer can be found.

The system “The buyer - Retailer – Resource management system – The environment" is offered which directed to increase the social interaction efficiency at purchasing. Analysis of factors affecting system operation efficiency is conducted.

Received results can be used in the up-today market analysis, planning, and simulation of visits of retailer, analysis of sales, manufacture of storekeeping strategy and deliveries on the market and analysis of buyers and their behavior. Research gives the opportunity to improve of the quality of customer service in urban retail considering emotional fatigue of the buyer.

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Conflict Control of Spreading Processes on Networks

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Abstract. The focus of this work is to provide introduction to the current state of art of the field of spreading processes on networks in connection with optimal control theory and game theory. This is challenging problem which remains open, so we present problem formulation, make suggestion of possible ideas of solution and show simulations to substantiate these ideas.

Keywords: Networks, game theory, optimal control, epidemic model.

1 Introduction and the Main Idea

This work presents development of the problem of conflict control of epidemic processes on networks. This area has been topic of research interest among different fields, including biology, computer science, economics, and the social sciences. Epi demic dynamic in population, computer virus spreading over communication network, and rumors or fake news widening through social networks are examples of very different processes with the same nature.

One of the first epidemic models was developed by D.Bernulli in 1760, motivated by smallpox in England. Later on, other researchers also studied mathematical models of decease spreading. These models were quite simplistic, but provided insights into mechanisms how different deceases can affect population. After initial development this direction of study become classical topic without promising findings. Recently, however, there has been returning to these problems due to “network paradigm”. Nowadays, we can see meeting in one point three different fields:

- spreading (for example epidemic) models [1]
- network analysis [2]
- game theory [3]

supported by parallel computational algorithms, sufficient to perform computation for networks dynamic in realistic scale. So far main problem was to build and analyze epidemic models, but today the point of efforts shifting towards effective control of spreading under conflict and uncertainty. Taking into account the most recent attacks on computer networks and security issues it is very natural to expand results to the field of malware mitigation [4]. Consider the heterogeneous SI dynamics:

$$\dot{p}_i = \sum_{j=1}^{M} \beta_{ij}\, p_j(1 - p_j) - u_i$$

where p_i is the probability of infection of ith node, β_{ij} - are elements of matrix with infection rates for every i-j node interaction, u_i - our influence on process, or in other words, control.

It is natural to set constraints for control in geometric and integral form

$$u_i \in [0, u_i^{max}], \int_0^T u_i(t)dt \leq u_i^{int}$$

also it is usual to define the objective function to be minimized (for example in form with linear costs):

$$\int_0^T (cp_i(t) + bu_i(t))dt \to min$$

For this problem there is idea to use Pontryagin's maximum principle. As shown in [5] (for simplistic setup) that the optimal solution is in form of bang-bang control. Our main goal to extend this approach for more general setup.

Consider a network, defined by adjacency matrix $A = \{a_{ij}\}$. Dynamic of epidemic process on this network is described by system of equations:

$$\dot{p}_i = \beta(1 - p_i) \sum_{j=1}^{M} a_{ij} p_j$$

with p_0 - vector of initial infection probabilities.

Optimal control idea. Control $u_i(t)$ could be applied to (every) node to delay spreading process. The main goal is to delay infection with minimal cost.

Conflict-control idea. If we reformulate original problem to set imaginary "player", responsible for infecting. Let us define $v_i(t) = \beta(1 - p_i) \sum_{j=1}^{M} a_{ij} p_j$, then the process

$$\dot{p} = v - u$$

is a conflict-controlled process [6]. The goal is to find $u_i(\cdot)$ as a function of $v_i(t)$ to protect the network from infection (or at least formulate conditions when it is possible to do). This is challenging problem which should be supported with theoretical and practical tools to analyze.

In this work we provide a simulation tool to compute spreading process (in SI model setup) for arbitrary networks.

2 Simulations

Simulation models were developed using R environment and available for working at [7]. For arbitrary network topology and initial infection distribution we run SI model and calculate spreading process on the network. There are two input files: network structure – .csv file with pairs of nodes. Each pair is a connection between them. Second file is names of infected (at the beginning) nodes. There are two methods implemented – network dynamic without additional infection (classical SI model) and network dynamic 2 – infection, which gives influence on other nodes starting from any non-zero level. The results are presented on Fig. 1.

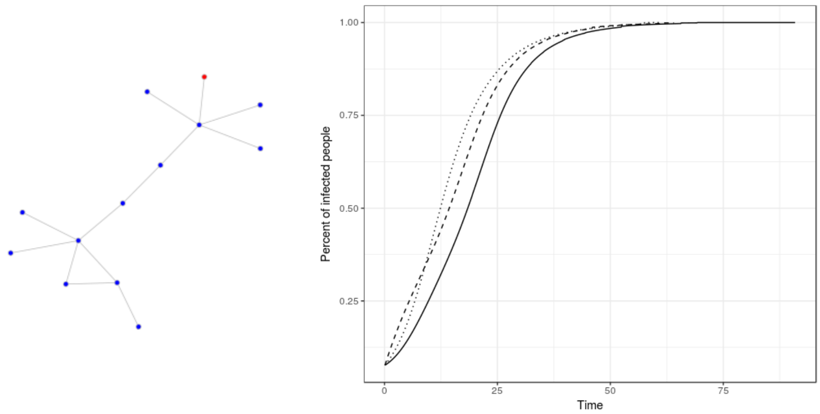

Fig.1. Example network topology and spreading graph.

Solid line shows dynamic for the case when infected node is at the most distant node from the center. Dotted line is for the case when infected node is on the border. Dashed line is for the case when infected node is in the centre. As we can understand from simulations network topology has immediate and strong effect on the spreading process.

Second direction of simulations was to calculate bang-bang control and its effect on SI model dynamic [8]. On the fig.2 there is simple SI model for $\beta = 0.2$ and $p_0 = 0.02$. There are two controls: red (starts at 5 and ends at 10, power 0.07) and green (starts at 13 and ends at 29, power 0.24).

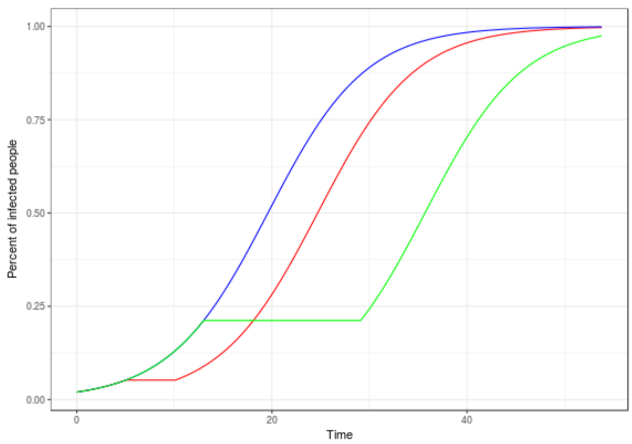

Fig. 2. Different setup of bang-bang control.

On fig. 3 it is shown result of different controls with the time of working 10 – 20 (red) and 15 – 25 (green). As we can conclude – it is much more effective to deal with spreading at the beginning them after some time.

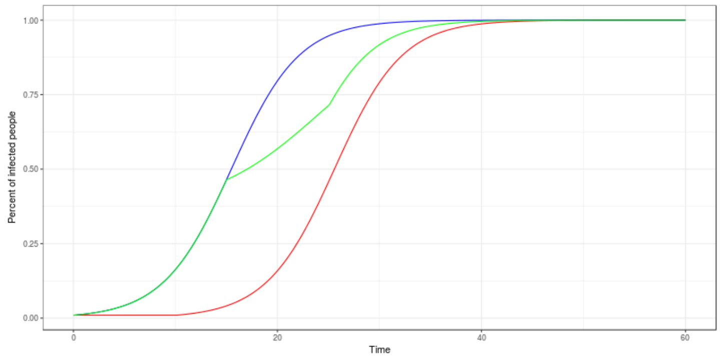

Fig. 3. Step-type control with the same power.

In this work we present tool for network simulations, developed to get better understanding of spreading dynamics. Also we create bang-bang control simulation to illustrate its efficiency.

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Analysis of ICT Application in Technology Transfer Management within Industry 4.0 Conditions (Education Based Approach)

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Abstract. The article deals with the analysis of information and communications technologies (ICT) role in the interaction of Higher Education Institutions (HEIs) and industry in the context of Industry 4.0 industrial system formation, as well as the implementation of the world experience in ICT-innovations applications in technology transfer and production processes. The study is based on the idea, that within Industry 4.0 HEIs are becoming the centers of technological clusters and networks and therefore education in such zones should be focused on achieving of real project results, conducting practical research in conditions of access to huge volumes of information, especially experiment data and tacit knowledge exchange. So it is proposed to consider ICT role within the HEIs place in Industry 4.0 innovation system, which requires new skills. Authors have considered the main Industry 4.0 trends within the education foresight methodology. Based on research results the main directions of ICT-innovations application in technology transfer system were formulated. The main issues and cases of ICT application in HEIs for technology transfer management thought the information-technology support of client-oriented approach to educational programs formation and the creation of smart environment of HEIs were considered. ICT role in educational engineering within the framework of HEIs strategy development at different levels as a mechanism for overcoming the contradictions between the prospective professional competences and the requirements from industry was considered. The given recommendations can be used by policy makers, managers of education and/or R&D organizations within the technology transfer and innovation education technologies implementation projects to improve the interaction between HEIs and business.

Keywords: Digitalization, Technology Transfer, Cooperation, Education, Industry 4.0, ICT, Innovations.

1 Introduction

The global economy is at the stage of transition to 4th technological revolution, which is based on the different solutions of network and adaptive production with intelligent systems. However, in order to take all advantages of Industry 4.0, the radical changes in the labor market are needed according to the changing requirements and, as a result, in education concepts, since human capital is the Industry 4.0 key success factor.

Therefore, now the nations need to start radically rebuilding the higher education system as a source of intellectual resources, modernizing the information and innovation communications of Higher Education Institutions (HEIs) infrastructure in order to create qualitatively new jobs and improve the technology transfer within the framework of business to education (B2E) & education to business (E2B) linkages.

Today the problem when the traditional education system prepares specialists for professions, which by 2020 can be partially or fully automated, is already clearly visible. All these professions require the routine work for execution, while the professions of the future are oriented to diverse social and creative skills, the ability to make decisions in uncertainty conditions and the ability to implement of complex projects. Thus, it is quite obvious, that the classical education system is obsolete and on the eve of the 4th industrial revolution calls for radical changes of R&D models.

At the same time the world leading manufacturers are already obtaining the benefits from advanced solutions (primarily from new generation of ICT solutions, especially intelligent systems). The survey, conducted by the American Society of Quality in 2014 among the manufacturing sector representatives, has revealed, that 82% of organizations, switching to «smart» production, have reported about an efficiency increasing, and 49% have noted the product defects number decreasing and another 45% have reported about the customer satisfaction increasing (Griffith).

Nevertheless, any manufacturer to obtain benefit from the transition to the future factory technologies, need to attract the qualified technical specialists, who are able to work with new virtual models of technology transfer as production base paradigm in the physical space and understand, what is required from them in new conditions of Industry 4.0. This is becoming a new kind of challenges for HEIs and education technologies (EdTech), so some leading world educational organizations with technical priorities already are actively developing of new approaches to training staff with the appropriate skills required in the future Industry 4.0 factories.

In these conditions the developing countries, those are not easily transitioning to the digital platform economy because of absence of global oriented national digital platforms and successful companies operating in new high-tech markets. In general, the digitalization of production and technological processes goes in information and communication technologies (ICT), finance, trade and some other service sectors. But these achievements could not provide stable competitive base of nation.

Experience of USA, EU, Japan and China, which hold the first positions in the production of applied full-fledged digital platforms in science, telemedicine and industry and other sectors, which are based on active cooperation in the framework of business to education (B2E) & education to business (E2B), clearly demonstrates the necessity of system policy of ICT development, which includes strong education component and important role of HEIs in technology transfer. This component is based on new education models within Industry 4.0 development patterns and includes science and technology transfer as an education technology. So in order to catch up with the competitors and to develop of applied digital technologies to solve different social and economic development problems, it is necessary to move the whole higher education system linked with economy quickly and systematically into the digitalization zone.

2 Study of Modern Trends and Important Implications

In our study we will use the McKinsey & Co definition of term «Industry 4.0» as «digitization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber-physical systems, and analysis of all relevant data» (McKinsey & Co., 2015) [17]. From given definition we can underline the critical role of ICT in manufacturing systems, which forms specific task for education.

Within the EdTech and HEIs development priorities study we note the ideas of Shelzer R. (2017), the expert of Global Electronic Services, underlines, that in social environment terms Industry 5.0 will return focus to human dimension of manufacturing whereas Industry 4.0 is primarily focused on the technological development issues. E.g. with this focus returning to human, the fifth industrial revolution may require a new manufacturing role – Chief Robotics Officer (CRO) [28]. This position will require the experts, who specialize in human-machine connectivity and will be responsible for all things from making decisions on which machines or devices to add to the plant to improving of strategies for the production line optimizing [16].

In this example we can observe the necessity to create the new framework of strategical cooperation, especially between the ICT sector and humanitarian sciences through the digitization [4; 18; 25]. The main dimensions of innovation communications according to (Pfeffermann, 2011) are derived from the conceptual definition of innovation communication and understood as the constitutive elements of the dynamic innovation communication capability [21].

This idea can be explained by Kelli [10], which underlies, that each person in the future will face with the «newbie fate», when we will just struggle to keep up with the progress, because of such main reasons:

- majority of the most important technologies, that will determine the life and competitiveness in the next 15-20 years, have not yet been invented, so they will be new to the business and society;
- new technologies require endless updates and users will constantly be in the status of newcomers;
- today the technologies obsolescence cycle has significantly accelerated (for example, applications for phones remain relevant for an average of only a month), users simply do not have enough time to master everything in a perfect way, until something else will replace it.

From the point of view of the business strategy, these reasons lead to a constant search for ideas and a rapid innovation process, which forms new tasks for HEIs, especially future engineering education.

According to studies [6; 7; 8; 26] there are such implications for the future engineering education in Industry 4.0 conditions:

1. Excellence through the interdisciplinarity, which is based on the ideas, that without interdisciplinary cooperation there are no innovations; highly complex socio-technical systems development requires the various academic experts collaboration; future engineers need the skills to «look beyond their own nose»;
2. Adaptability to the rapid innovation cycles («half-life» of knowledge sector is shortening rapidly; students need less detailed specialized content than the lifelong learning ability; future engineers need the skills to adapt to rapid changes);
3. Survival in Industry 4.0 conditions requires good IT skills (IT is the main driver of innovations in future industrial context; independent in specialization engineers should have the basic knowledge for understanding of others; future engineers need to be able to «speak code» as a new competence);
4. New business thinking (above the basic classical skills to manage projects, future technological entrepreneurs need of additional skills, particularly leadership, decision making etc.; they need to know how to communicate in business ideas with different stakeholders; future engineers need to know how to collaborate);
5. Taking risks and dealing with uncertainty (uncertainty cannot be managed and even the best prediction will end up as «only partially correct» and that's why good predictions need some time, which is lost for other things; future engineers need to be unterrified and capable to adapt to the changes quickly and through the broad competencies);
6. Bursting with creativity (when the speed of innovation cycles increases, creativity becomes the "new gold" in business; students need the ability to critically assess different issues and to develop responsible and creative ideas and solutions).

In all of above mentioned points ICT play a significant role, because they allow to create appropriate education framework and environment for (1) interdisciplinary cooperation through the simulation and models (e.g. these are already used within the new nanomaterials development [30]); (2) lifelong learning as an education tool; (3) coding base which is an element of digital competence; according to forecasts, in the next 10 years the number of jobs requiring programming skills, will grow faster than other labor market positions; (4) business already requires a culture of interaction, when managers and professionals can exchange information that is important for improving processes and efficiency increasing, as well as for eliminating problems and adapting to changes; (5) ICT can be considered as a tools for uncertainty reduction i.e. it can automate the process of situation assessing and decision making under uncertainty conditions; (6) creativity can be developed by providing training in modern and promising IT by including the student in the process of knowledge obtaining, new IT solutions and new technologies development within the Smart Education framework.

Analytical materials [2; 11] show, that the forthcoming technological revolution must turn the educational system towards the training of predominantly new-quality technical personnel, the deficit of which will create problems in technology transfer for science based business and state as well.

In view of the foregoing issues, the problem of choosing a strategy and directions for technological development for different entities is somewhat simplified and can be conditionally reduced to the task of current demand analytics in the labor division global system. Meanwhile, despite the presence of significant number of economic and technological forecasts, as well as foresight researches, the task of selection of technological development promising areas for regions, companies, HEIs and other entities is not a trivial [12; 24], because of such points:

- these documents are largely generalized and do not fully take into account the specific features of particular region or company. In addition, as a rule, technological areas are also considered in aggregate form. In this case, technologies in the age of 2-3 years can be identified within the technological field actively developing on a global scale, which has been developing for several decades;
- in order to find own place in the technological trend, it is necessary to examine and objectively evaluate own competencies, as well as the market needs;
- taking into account that many technologies have global distribution, applications and markets, it is important to take into account the possibilities of collaboration with domestic and foreign partners in R&D, as well as possible limitations determined by state regulations, and in some cases, sanctions or restrictions (e.g. intellectual property or export).

Thus, when choosing the strategy and directions of technological development, the subjects acquire special importance the tools and methodology of detailed research of technological and competitive aspects of perspective directions of development.

Realizing this, the world's largest IT companies are already laying out in their strategies the popularization of programming and engineering through the cooperation with the educational sector, treating it as a source of staff and ideas.

Apple launches Swift playgrounds to teach children programming, and the creators of the largest organizations sponsor the online platform code.org. Different components are developed at a tremendous speed, which leads to the fact that now the child can assemble the desired construction from LEGO Robotics or take the Arduino controller and create something completely unique.

In 2014, developers from Osmo have created the game Osmo Pizza, which taught children the basics of programming. It was included in the list of 25 best inventions of the year according to Time Magazine. Tynker plans the introduction in more than 60,000 US schools to teach children the basics of coding through the programming of Parrot drones. It is possible, that soon we will see kindergartens, where educators with tablets will teach children in foreign languages, mathematics and programming. All this is the first stage of training future specialists for the industry 4.0. If children do not begin to teach technical principles from an early age, then in the future it will be increasingly difficult for them to adapt to the professional environment.

Modern technologies accelerate the learning process and also help the trained professionals in the work. And this concerns not only artificial intelligence application. In the near future, virtual reality technologies will help medical students to perform practical operations without harm to patient.

Another example of new technological level is Next Galaxy Company, which creates a single social VR platform CeeK. The plans of developers include making a whole virtual world with shops, meeting places and classes for training.

These examples illustrate the moving towards new development approaches, but within the framework of national development programs and implementation of national priorities as well as priorities of education system as a base of national innovation system, HEIs also have an important role to play.

In United States, that is an example of nation, where the system of forecasts is directly implemented into the state policy in order to achieve the national competitiveness, since 2012 there is a non-profit Coalition of Smart Production Leaders, which, in addition to business entities, includes state agencies, HEIs and labs. Also in USA, the US Production program is being implemented, within the framework of which it is planned to create up to 15 applied research institutes for innovations development in the manufacturing industry (IMI) in such areas as sensors, optics and photonics, materials, artificial intelligence, robotics, modeling, additive production, 3D-printing etc.

In Germany the platform «Industry 4.0», which was created in 2013, is one of the key development mechanisms. It works in 10 strategic development directions: creating conditions for Industry 4.0 technologies transfer to SMEs, cyber security, regulatory, best practices demonstration, Industry 4.0 technologies standardization etc.

Analysis of all these examples demonstrates the key role of ICT, which act as an instrument for creative skills developing, as well as a promising direction for the development of E2B & B2E as well as S2B & B2S cooperation. So in the world practice, the most successful HEIs combine scientific, engineering, humanitarian, medical, business schools and faculties in their campus. As a result, a competences complex arises, that can be used to implement projects of any complexity. This is appreciated by global companies and creates an effective entrepreneurship environment.

According Marvin Liao, partner of 500 Startups Foundation, [29], there are many factors, that confirm the promise of work in the field of EdTech. On the one hand, this is a reduction in the cost of consumer goods, on the other it's still high prices for education, for example, in North America. Despite the fact that in many countries the sphere of education is subject of very serious regulation, in the next 10 years exerts expect the development in this area as well.

The development of proactive strategies is prompted by forecasts according to which the repeated change of professions will be a characteristic feature of the Industry 4.0 economy (according to estimates of City&Guilds, Great Britain, by 2025 people will change their profession up to 19 times), and the fact that professional knowledge quickly become obsolete (annually in the world economy more than 500 professions dies, more than 600 appear). In a number of industries, innovation cycles are shorter, than the time required for appropriate specialists training.

In Ukraine, the strong engineering competencies are not backed up by business skills, scientific schools lack engineering, there are practically no incorporated medical schools anywhere.

In current conditions in the Ukrainian ICT industry there are practically no well-established connections between HEIs and business, scientists and infrastructure, the state and start-ups, which leads to the loss of development resources. There are no efficient companies (networks) for technology transfer, venture funds and full-fledged intellectual property protection. It is difficult to interact with industry in the absence of special services in many HEIs, which monitor personnel requirements, evaluate potential cooperation opportunities (E2B & B2E, S2B & B2S), plan research and implement their results. As a result, potential customers have fragmentary information about the scientific and production capabilities of HEIs and are practically unaware of the competitive developments. Let's note, the same situation is observed in other high-technological sectors, which creates threats to national security through the possibility of reaching to the global innovation development periphery.

The special importance of technology transfer in the HEIs development is caused by the fact, that education quality implies two components: getting new knowledge and it integrating into the real life (production). Only the fulfillment of both points makes it possible to obtain practical skills, which will help in development purposes.

So the **purpose of this study** is to analyze the role of ICT in the interaction of HEIs and business in the context of Industry 4.0 industrial system formation, as well as the introduction of world experience in using ICT-innovations in the technology transfer and production processes. Based on the results of the research, the main directions of the work on the introduction of ICT-innovations in HEIs technology transfer system will be formulated; obtained results can be used to develop projects to improve the interaction between HEIs and business.

3 Methodology

In UNESCO documents, education technology is considered as a systematic method of creating, applying and defining the entire learning process of teaching and learning, taking into account technical, human resources and their interaction.

In this case the efficiency of ICT application and technology transfer is determined, first of all, by an adequate organizational system, oriented to ensuring the process of R&D results transfer into production and their subsequent distribution in the economy.

For the development of educational system adequate to Industry 4.0 we propose to use such methodological points and suggestions.

First of all we propose to conduct the technological trajectory analysis in the context of innovation management framework (high-tech case) [14], which gives possibility to form the vectors of education system development according to future technologies, e.g. considering the role of ICT as connecting link.

We also propose to consider ICT role within the HEIs place in international innovation networks, which are the new stage of innovation development [3; 13] and requires new skills.

In our previous studies we have considered strategycal aspects of technology transfer in metallurgy [19] and technological package concept for space metallurgy development strategy [20]. These ideas were based on different ICT tools applications, which help to unite various technologies within the complicated technological systems (firstly within some theoretical models and simulations) and manage them.

Another aspect of Industry 4.0 implies the rational use of natural and technical resources, the most effective energy saving, recycling of all waste and the receipt of new products, raw materials or energy from them [15]. This aspect also deals with the education and transfer of energy efficient technologies.

We propose to consider all these aspects within the education foresight methodology. Generally foresight is a system of methods for expert evaluation of strategic directions of socio-economic and innovation development, identifying technological breakthroughs, that can have an impact on the economy and society in the medium and long term. Expert assessments are the basis for the future options evaluating. Foresight methodology has absorbed dozens of traditional and fairly new expert methods. At the same time, their continuous improvement and development of methods and procedures are taking place, which provides an increase of the prospects for scientific, technical and socio-economic development foresight validity.

The information base of the educational foresight includes analytical reports of international organizations, materials of foreign foresight centers, forecasts of large corporations and private companies, data of consulting agencies, national forecasts of scientific and technological development of various industries, databases of scientific publications, patents and dissertations and other sources.

The main vector of foresight methodology development is directed to a more active and focused use of the knowledge of experts participating in various projects. Usually, each of the foresight projects uses a combination of different methods, including expert panels, Delphi, SWOT-analysis, brainstorming, scenario building, technological roadmaps, relevance trees, mutual influence analysis, etc.

Within the purpose of this study we underline, that foresight proceeds from the idea, that the onset of future desirable version largely depends on the actions taken today, so the choice of options is accompanied by the development of measures that ensure the optimal trajectory of innovation development.

Most foresight projects as a central component include prospects of science and technology development. Usually these issues become a subject of discussion not only for scientists, but also for politicians, businessmen, practitioners from different sectors of the economy. The result of such discussions is the emergence of new ideas related to improving the mechanisms for managing science, integrating science, education and industry and, ultimately, increasing the competitiveness of the country, industry or region.

Having an idea of the potential of digital transformations and the principles of integrating a physical plant with a real-time digital model that bidirectionalizes what is happening in the virtual and real worlds, HEIs will be ready to occupy a niche of future experts and active participants in the industry economy.

In Fig. 1 we have shown the basics of foresight application for higher education digitization according to technology transfer development.

We believe that analysis and forecasting within the education and technology transfer objectives should include:

– formation of data on the state and prospects of the industry development in the

country and abroad;
- monitoring and analysis of production and sales volumes at home and abroad;
- expert-analytical studies in the development of strategic industry documents;
- monitoring of measures of state regulation and analysis of their impact on the development of the industry;
- analysis of key technological development trends: global prerequisites, key challenges and risks, international experience, current status, etc.;
- examination of investment and innovation projects of the industry development.

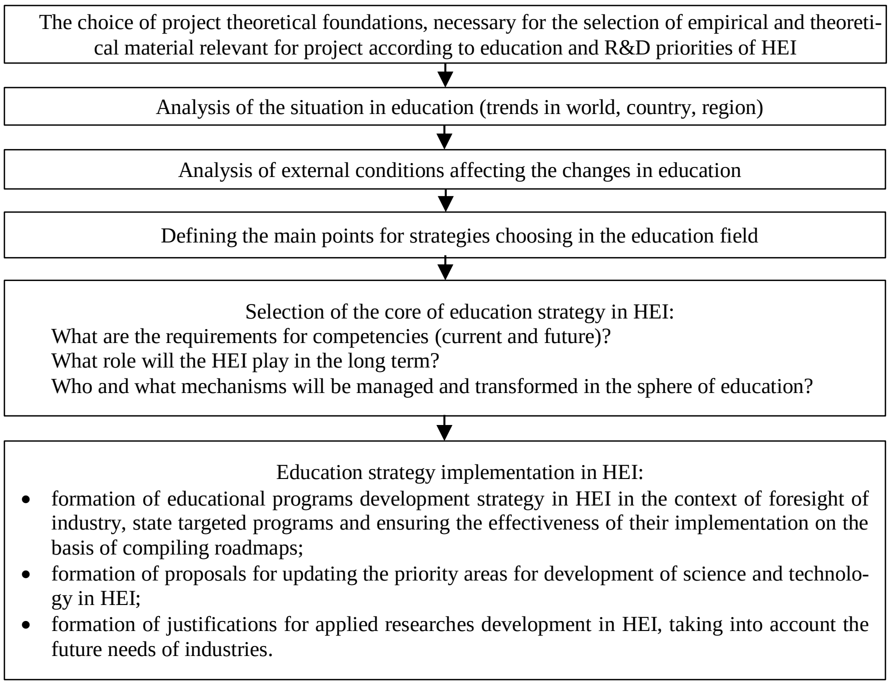

Fig. 1. Education foresight framework in HEI.

According to Fig. 1 we see, that in conditions of HEIs autonomy the new strategy should be developed by each HEI according to its specific, so the role of innovations (organizational and technological), particularly ICT, is growing.

4 HEIs Technology Transfer Models Evolution

From the previous points we can conclude that in education an era of radical change is coming. For a very long time this sphere could afford to be immune to all possible to changes in society so that behind it the reputation of one of the most conservative areas of human activity was fixed, but in Industry 4.0 times the situation is changing. The next 20 years will be the period of the most radical changes in education, perhaps from the moment, when national educational systems was created. And the main source of these changes will not be the education system itself, but linked industries and technologies, which will come along with a change in the technological era.

Based on analytics of foresight studies and world ranking methodology the evolution of HEIs models according to ratio of three criteria (integration of R&D activities in education process, cooperation with business and society, digitization), was developed (see Fig. 2). According to Fig. 2 innovation production become the main functions of University 4.0, as well as the formation of communities of a new level – «thinking environment».

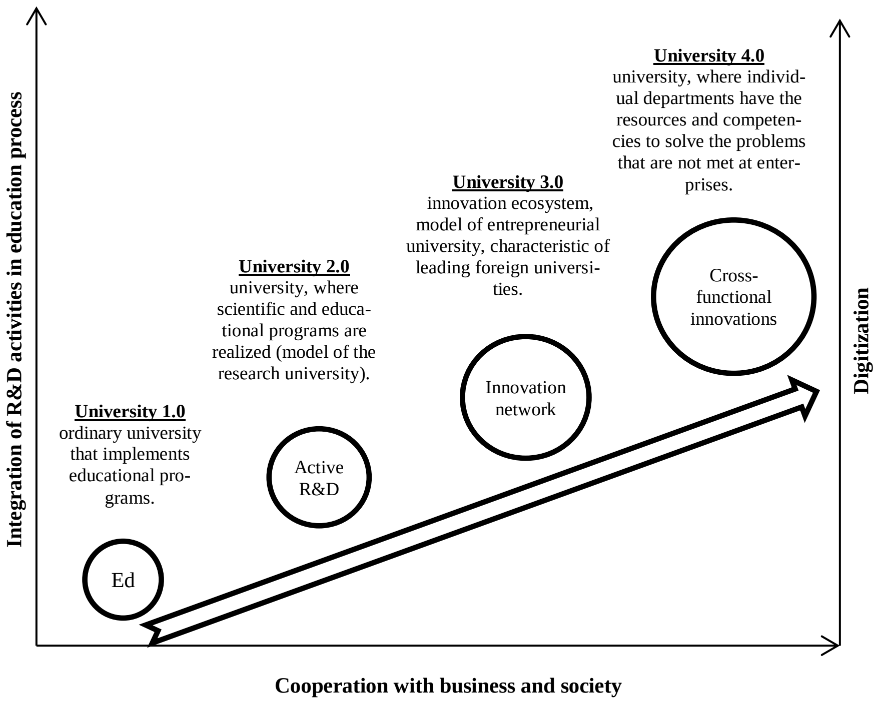

Fig. 2. University models evolution.

As part of digital economy within Industry 4.0 development, HEIs are becoming centers of technological clusters and networks (innovation zones), such as it is in the Silicon Valley and Stanford University. Education in such zones is focused on achieving real project results, conducting practical research in conditions of access to huge volumes of information, especially experience data and tacit knowledge exchange within the cooperation technology transfer models. A new environment around HEIs (so called "innovation ecosystem") helps to form consumers (particularly through the spin-offs) with a new way of life that will stimulate a cyclical demand for innovation.

According to these trends up to 2030 a «flipped university» can become a typical educational model, in which training is conducted through mass open online education platforms such as edX, Coursera, etc., and only the laboratory works, training projects and lively discussions will be realized in HEIs. Education 4.0 allows the use of different educational practices: mixed instruction, individualization, project work and adaptive learning.

It should be noted, that an important condition for domestic R&D sector effectiveness increasing is the implementation of measures to deepen the integration of science and education, including, in particular, the creation and development of integrated structures: departments and laboratories of HEIs in academic institutions, university and interuniversity complexes, educational & industrial centers, specialized (sectoral) research HEIs and departments.

In new conditions it is no longer the main question of how to develop a product and promptly transfer its technology to production. To create a finished product we require a holistic approach to its development and production. Therefore, there was a need for a global change in the education principles with the transition to holistic learning in order to catch up with the emerging in industry trends.

The use of digital and virtual engineering makes it possible to carry out research and development in computer-aided design systems, which affects the quality of the product and the timing of product withdrawal to the market. Industrial Internet, which involves connection to data networks of various production systems, allows to receive the necessary data in a timely manner and to act remotely on equipment, which ultimately affects the increase in production efficiency.

So the new EdTech should include collaborative activities, digital support systems (augmented reality), automated vehicles, predictive maintenance, cloud technologies, sensor materials and stand-alone components, advanced analytics (analysis of big data), intelligent planning and production control are part of technologies list that gradually are transferred to industry and allow enterprises to reduce production costs and energy consumption, increase labor productivity etc.

5 ICT-Based HEIs Strategy

In the context of education strategy in the new information and communication environment discussion, it is necessary to take into account that there are more complex tasks, that some HEI alone are not capable of, so HEIs need cooperation with foreign and most advanced HEIs, large world companies that have their own large departments of strategic planning of the educational market.

Digitization is connected with important task of HEIs open information exchange system with the external environment development. For these purposes, it is necessary to create communication platforms in HEIs for representatives of state authorities, business, scientific and educational and expert community, as well as civil society. It is also important to establish mechanisms for systematic interaction with graduates, to implement programs of sociological and monitoring research in the field of science and education, and to create open e-libraries of research papers of employees and materials of conferences, held at HEIs.

These all tasks are based on understanding, that within Industry 4.0 the employer can be considered as a source, which allows HEIs to create the necessary interdisciplinary educational programs and to adjust research strategies with strong evaluation and feedback component. As a result, emerging market the needs must find a rapid response in education. So we came to the individual education paths formation according to customer requests, which is caused by such reasons and education trends:

- new players (informal educational institutions, corporate programs, online platforms etc.) already offer individualized educational products, that meet the needs of students and, what is the most important, employers;
- the number of informed students (so called autodidacts), who are able to formulate their learning goals and necessary competencies set, is growing;
- demand from employers for specialists with a certain and confirmed set of topical competencies, that are able of bring innovation ideas to company without any time gap, is growing.

To meet all these challenges and to achieve all these goals, each HEI needs a strictly individual strategy of digitalization, and it is not tied to the learning process, but to practical scientific activity and to existing and future developments.

The main here is the fact, that within these trends, ICT allow to return the individual approach to the center of the educational process within the competence model.

When the HEIs will combine digitization and R&D strategy we can create «growth points», that will prove the effectiveness of ICT in practice, and at the same time the ICT modernization strategy will have a deterministic character and will be based on the real strategy of HEI development as a scientific & educational organization, and not from the some abstract representations.

At the same time despite the some sectoral differences, HEIs have common tasks and ICT tools, for example:

- creation of databases, systems for questionnaires and entrants tests processing, archives of specialized literature and scientific works, information visualization systems;
- creation of complexes for creating 3D-audiences, many screen projection systems, transmission and reproduction of visual information over a wireless network;
- digitization of auxiliary activities management. Most HEIs primarily automate financial and HR activities. But the systems of educational process management, electronic training, document circulation and automation of libraries are also claimed;
- equipment and other resources for data centers creation, network infrastructure systems and labs for experiments with hardware and software solutions.

Another part of digitization and R&D strategy deals directly with Industry 4.0, which is based on new skills.

As part of the HEIs education strategy for Industry 4.0, it should be noted that the students will have to master three non-traditional skills.

The first point for students will be understanding the principles of hybrid work system application in the combination with technical assistance and cyberphysical systems.

The second point deals with the digital design environment. In the past, students had to deal with one thing: only with CAD systems, process engineering or robot modeling, in Industry 4.0 they have to work with all three digital tools that are used in modern first-class production.

The third point deals with the ability to manage intellectual production, proceeding from the extremely diverse requirements of customers, taking into accounts both the autonomy of technological systems and their interconnection.

Such skills requires abandoning of traditional education methods, when subjects are broken down into disciplines, so that students can gain a comprehensive understanding of the interrelationships and interdependencies between mechanical, information and automated processes.

Thus, an important aspect of HEIs adaptation to Industry 4.0 realities is the search for technological and ICT solutions to implement the above-described trends in the formation of educational programs and the transition to a new model of the scientific and educational process and to support the full life cycle of scientific and educational products (real education projects), taking into account its ties with the real sector of the economy.

In the near future, those universities, that will be able to use the ideas laid down in Industry 4.0 concept, will be competitive in order to individualize the trajectories of preparing graduates in the format of Lifelong Learning.

Based on the analysis of research [27] and models of competences, developed by the Employment and Training Administration (ETA) and Automation Federation of Industry experts [1], and approaches, considered in study [22], information-technology support of client-oriented approach to educational programs formation and the creation of HEIs smart environment of technology transfer can be realized through the application of such ICT groups within the ICT package of HEI (see Fig. 3).

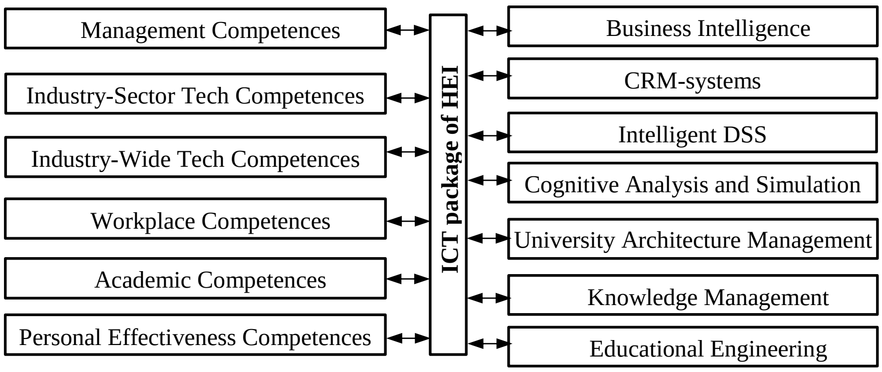

Fig. 3. ICT tools for technology transfer competences development in HEIs.

The simplest effect for the new EdTech deals with the animations based on Flash technology, mobile applications tools and media services application.

Educational engineering in the framework of HEIs strategy development at different levels can be considered as a mechanism for overcoming the contradictions between the wording of professional competences from educational standards and the requirements of labor functions from professional standards.

Among the engineering methods the information and educational space semantic modeling methods can be highlighted, which make it possible to systematize knowledge of professional field in the form of conceptual models of ontologies and repositories of educational objects [5], which will later be used in the design of curricula, course content and education strategy based on real projects.

Business Intelligence systems as set of technologies, software and practices aimed at achieving business goals by making the data best application available can help to solve different analytical tasks of HEIs R&D management (R&D priorities selection, cluster policy etc.).

Also within the smart environment of HEIs we propose to consider the management of HEI architecture based on University Architecture Management, which can help to adopt the university processes to new environment.

6 Conclusion

The fourth industrial revolution encourages everyone to adapt faster and, therefore, the situation, when success is achieved by those companies that work closely with universities and startup centers and introduce modern technologies in production, is clearly visible. Development of almost every of the basic industries of Industry 4.0 is impossible without solving the staff issue, as well as the creation and implementation of innovation technologies. So the range of the digitalization and technology transfer problems in the context of Industry 4.0 formation is aimed at the integrated development of HEIs` ICT based innovation ecosystem, synchronization of work with the innovation infrastructure objects, cooperation development with high-tech business in the frame of personnel training, applied research implementation and intellectual activity results commercialization.

In these conditions ICT application strategy should be aimed at supporting the creation of integrated education programs, which include the training of personnel, who have the necessary skills and knowledge to work in the new environment of Industry 4.0 through the new technology transfer models. Also, in the framework of development strategies we need to consider such main aspects of digitization:

- creation of digital competencies centers and stimulation of applied research and development within the education process;
- development of high-speed and reliable data transmission networks for educational and analytical purposes;
- creation of pilot digital factories to popularize the digitalization process across the entire spectrum of HEI specialties;
- raising awareness in the business environment of new opportunities and the need for cooperation with HEIs;
- creation of new type of network technology transfer tools based on the smart production with its combination with education (“R&D + EdTech” model);
- creation of specialized communication platforms with business in Industry 4.0 areas.

7 Acknowledgement

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Building an Extensible Symbiotic University-Enterprises Cooperation in Ukrainian Game Industry

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Abstract. This paper describes the current state, the process, and the attitudes of cooperation between Kherson National Technical University and game industry companies in the frame of Erasmus+ project "University-Enterprises Cooperation in Game Industry in Ukraine" (GameHub). The work on the project in Kherson National Technical University is reported in the paper. It covers monitoring of the competence profiles needed on the game industry market, creating necessary infrastructure and developing the relevant curricula, study programs, education resources, and organization of the feedback loop with game industry enterprises. One of the priorities is to equip students with soft competencies needed for game industry such as creativity and academic integrity. The paper also presents the actual cooperation results, which could be helpful for Ukrainian higher education sector to respond to current and future education needs because mutually beneficial and sustainable university-enterprises cooperation can achieve a better match between competence profile of university graduates and those required by game industry.

Keywords: Cooperation, higher education, gaming industry, infrastructure, curricula, competencies

1 Introduction

Current state-of-the-art of the game industry (GI) in Ukraine is dynamically developing and becoming attractive for many international game application development companies. Developing Ukrainian GI is stimulated by a wide spreading of computer games among children and young people, active using of computer games in education, mature computer game marketing with well-established methods of monetization. On top of it, Ukrainian information technologies (IT) sector is proved its ability to develop and promote software of high quality.

Even with all things considered, preparing specialists for GI in Ukraine is complicated by a deficiency of narrowly focused specialists such as graphic designers, content managers, storytellers, scriptwriters, sound designers, sound programmers, web-client programmers, sketchers etc. A majority of Ukrainian universities don't have necessary software and hardware to equip laboratories for training such specialists, as well as appropriate curricula and educational programs of courses related to the development of competencies needed for the work in game development companies. There is a gap between educational supply and the demand of GI market. Needs of this market in Europe and in the Ukraine force the enterprises and the universities to cooperate for the purpose of overcoming the above-mentioned complexities on mutually beneficial conditions.

The higher educational system in Ukraine is traditional and conservative. The nature of the GI sector requires of Ukrainian university developing a new conception of computer game development education providing students with the solid technical knowledge and skills, at the same time enabling them to focus on the transversal components of computer game design. The practical experience may come from the cooperation between the university and national game industry.

Although Ukraine has legislation and strategies for university-business cooperation improvement, in many cases these strategies are not implemented. Mismatches between employers´ needs and what universities offer lead to skill gaps and economic underperformance. Therefore, the number of engineers-graduates with the competencies that fit the game industry employee profiles is almost zero.

University-enterprise cooperation has been a subject of debates and a focus of attention for many years and is commonly defined as all forms of interaction between universities and enterprises for the reciprocal and mutual benefit. In recent years, it is being developed rapidly and markedly through implementing Erasmus+ projects in the Europe [1-3] such as “Integrating Entrepreneurship and Work Experience into Higher Education” (IE-WEXHE), “Embedding Entrepreneurship Education” (Triple-E), “European University-business cooperation” (UBC) and others. The European project “Integrating Entrepreneurship and Work Experience into Higher Education” (IE-WEXHE) is aimed at the integration of higher education and enterprises. The project assumes generating case studies of work-based learning involving four types of disciplinary sectors (hard-pure, e.g. natural sciences; soft-pure, e.g. humanities and social sciences; hard-applied, e.g. medicine and soft-applied, e.g. social work) covering work placements, traineeships, and entrepreneurship. A unique feature is an attention to Humanities for which the transition to the labor market is less transparent and mapped than other sectors. The project “Embedding Entrepreneurship Education” (Triple-E) has been designed with the objective to increase the proportion of University students acquiring an entrepreneurial mindset and engaging in early-stage entrepreneurial activity [4]. The project “European University-business cooperation” (UBC) is aimed at conducting a Europe-wide study on cooperation between universities and business. This study is the largest study ever undertaken on the topic of UBC in Europe [5].

The problem of university-enterprise cooperation has been insufficiently studied in Ukraine. As a result, over the past decades, we have seen a disconnect between Ukrainian education system and the labor market.

All above-mentioned problems have stipulated initialization of International Erasmus KA2 project “University-Enterprises Cooperation in Game Industry in Ukraine” (GameHub) aimed at maintaining University-Enterprises cooperation in Ukraine [6].

2 GameHub Project

GameHub project is aimed at the construction of the infrastructure, which allows students to improve their skills and competencies needed to work in GI and intends cooperation between universities and enterprises. The paper dwells on such cooperation organized in Kherson National Technical University (KNTU), which is the member of the international consortium of GameHub project.

The work on the international project GameHub started in October 2015. The project is aimed at developing the methods of teaching the students, veterans of anti-terrorist operation (ATO veterans) and unemployed engineers the competencies and skills needed to create computer games.

The main tasks of the project are the following:

1. Developing the map of the competencies, which can determine a professional level in GI, as well as the instruments for monitoring the competence profiles [7-9];
2. Preparing the university staff;
3. Developing 18 bilingual learning modules.

GameHub consists of four main components:

1. Pedagogical component, which includes a methodology for learning the students, ATO veterans and unemployed people how to create game applications according to the developed modules;

2. Technological component, which includes creating and maintaining the work of game laboratory;

3. Methodological component;

4. Informational component, which involves providing communication between the main branches of GameHub members:

- teachers and trainees/students, unemployed people, and ATO veterans;
- university management / GI representatives and employers;
- scientists / scientific society.

The work on the GameHub project in KNTU started with monitoring of the competence profiles needed on the GI market in Ukraine, creating necessary infrastructure and developing the educational resources.

3 Goals and Objectives of GameHub Functioning in KNTU

GameHub in KNTU is a necessary and essential tool for the creation and implementation of new educational programs on computer games development. GameHub is also a tool to overcome a gap between the insufficient technological infrastructure of the educational process and the demand of GI market with the help of developing the game learning laboratory that provides students with the entire scope of the necessary technical knowledge and skills. As a result, implementation of project results helps the students to overcome some discrepancy between the knowledge gained at the university and the actual demand in the labor market.

GameHub in KNTU should unify connections between the university, game industry and society in general.

The goal of GameHub is the stimulation of the students and trainees to acquire of knowledge and practical skills required for successful work in the computer games development sector.

The objectives of functioning GameHub in KNTU are:

- Providing conditions for creation and implementation of an innovative education program on computer games development as a specialization for the students of software engineering specialty;
- Adaptation of education program on computer games development to the GI market and employer's requirements;
- Increasing the level of quality of software engineering specialists through learning state-of-the-art technologies of computer games development at the level of labor market requirements;
- Looking for the ways to improve the organization as well as scientific and methodical ware of educational process;
- Providing consulting services to the base of university and game industry connection;
- Reciprocal exchange of experience, knowledge, educational materials and innovation practice of engineering education between partner universities.

The target audience of KNTU GameHub is illustrated in Fig.1.

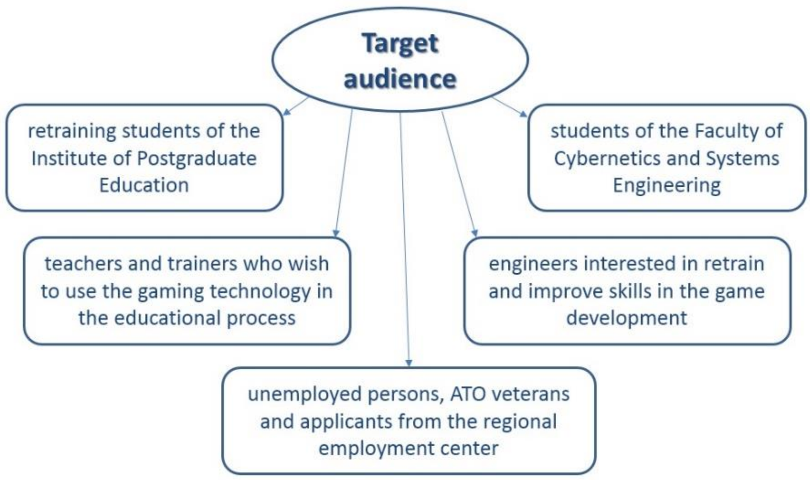

Fig. 1. The target audience of KNTU GameHub

The principles of the GameHub organization in the University (fig.2):

- Close collaboration with enterprises in the area of game industry on the regional, national and international levels;
- Implementation of modern innovative educational methods and methodologies;
- Adaptation of educational program to the labor market requirements;
- Combination of studying the students with practical activity;
- Gamification of the learning process;
- Intensive collaboration with partner universities.

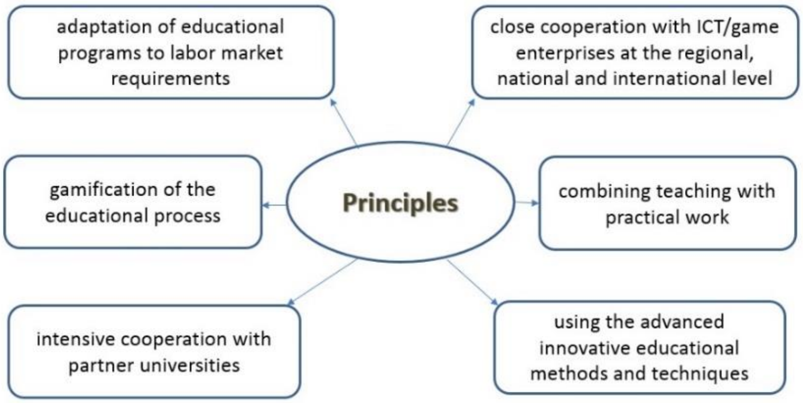

Fig. 2. Principles of GameHub in KNTU

4 Priorities of KNTU GameHub

The priorities of KNTU GameHub are illustrated in fig. 3.

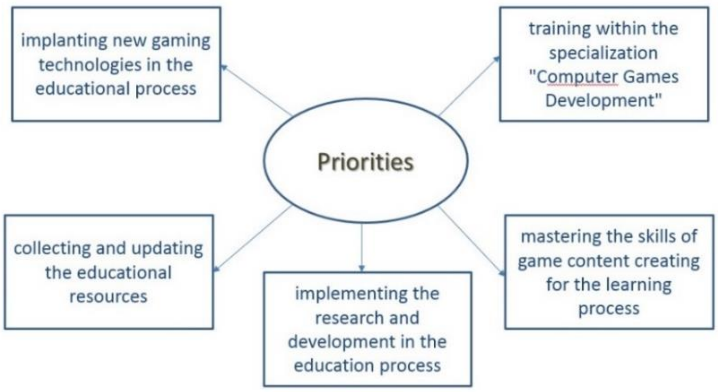

Fig. 3. Priorities of KNTU GameHub

All activities in KNTU within the project can be put into pedagogical, methodological, technological, informational, and academic components.

The ***pedagogical component*** (fig.4) of the GameHub project in KNTU includes the following stages:

1. monitoring the competencies needed for the GI market;
2. developing the competencies.

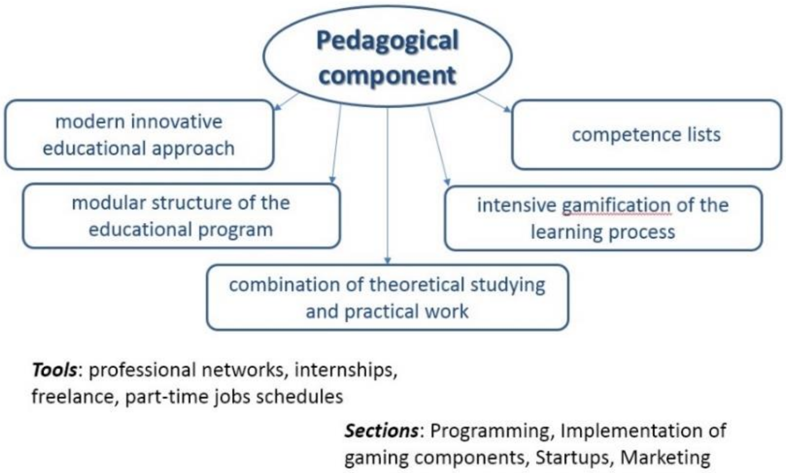

Fig. 4. The pedagogical component of KNTU GameHub

To monitor the competencies a thorough analysis of educational needs was performed using a survey among a wide variety of specialists, i.e. programming specialists (gameplay programmers, user interface programmers, database programmers), design specialists (gameplay designers, mission/quest designers, user interface designers, scriptures), art specialists (texture artists, animators, environmental artists, cinematic artists, user interface artists etc.), audio specialists (audio engineers, music composers, musicians). The survey was conducted based on the pre-developed questionnaires [7-9]. The analysis of survey results has helped us to determine the employers' needs as to the main competencies of GI specialists.

The analysis of the competence level of the teaching staff and students majoring in "Information technologies" was also conducted.

The analysis of educational needs is based on questioning of 203 persons: 18 GI specialists from 5 game development studios and companies, 25 University teachers, 160 students.

In consequence of monitoring the competencies, we have determined a set of competencies needed for the students of specialties related to the GI to meet GI market demands, and have formed the competence profile of IT specialist in digital GI paying attention to the specific competencies that should be obtained by a specialist in this field [7].

Game developers tend to work in diverse teams that require more creativity and interpersonal communication skills than traditional software developers. The monitoring has shown that the main competencies for the game developer are creativity, academic integrity, problem-solving, teamwork.

Creativity appeared to be an especially important non-technical skill that could be enhanced in students headed for game development careers [10, 11]. It's what makes the games unique and competitive in a market. Creativity allows developing new ideas and coming up with the ways to hold consumers' attention.

Problem-solving is also important competence needed for game developers. All software, in general, is designed to solve some user problem and within that general solution is a wide array of smaller problems that make it up. Programmers are problem-solvers by occupation, which it is one of the most vital soft skills for success in the industry. After writing codes and creating programs, programmers also find and fix any issues that may appear. This is not often an easy task since even the tiniest of errors has the ability to wreak havoc on a program.

Ability to work in a team in many cases can be the first or most important skill for game developers. Games companies involve groups of people, working together, to achieve the same final goal. Game developers must be good communicators, who can cooperate with people working closely with programmers and receive feedback from testers ensuring that the functionality of the game is practical and balanced. Unless a game developer can effectively deal with other developers, managers, and even customers, he will constantly face trouble despite how good your ideas are or how valuable his skills are.

Another competence equally important for GI is academic integrity (AI) [12, 13]. Academic integrity means academic honesty and implies that students and teachers abide by a code of honesty, trust, fairness, respect, and responsibility related to the production, publication, assessment, and exchange of knowledge in learning, teaching, and research. Maintaining academic integrity is an issue of concern to all the students due to high and rising levels of plagiarism and other forms of cheating such as receiving unauthorized assistance. Courses related to computer programming require special consideration because they are connected with the intellectual property, and use of the computer permits easy copying and modification of programs. The accusation of AI by students has serious consequences in their future workplaces. In the workplace, since the profit of game developers and their employers depends upon the uniqueness and originality of the code, a plagiarism or stealing the code can potentially harm the career.

The analysis shows that the and the level of knowledge and skills of University students in Information technologies do not satisfy the requirements of employers in the field of CI. During the analysis, it has been also determined that the level of foreign languages, programming and graphics environment of the students and teachers should be improved.

The relevant curricula and programs should be created to develop or/and improve the detected competencies specialized modular courses. Curricula and programs should be based on the alliance of theoretical learning providing a certain system of knowledge with the practical work providing a system of necessary skills through the active implementation of laboratory and practical tasks, training and work with potential employees, realization of creative ideas in the course works and graduation works, scientific work, taking part in startups etc.

To develop the competencies a learner-centered environment should be constructed, which is connected with some changes in practice. The first change relates to a switch from a perspective that the teacher is responsible for the learning to one that teachers and students share the responsibility for the learning. Working in small groups, when the students from each group have their own goals and work to achieve them, encourages students to take charge of their learning, trains their leadership skills. The second change relates to the content. The situation when teachers cover content and students acquire it should be substituted by using the content in the learner-centered classroom to construct knowledge. Active learning in the form of discussions encourage students to acquire an interest in learning by asking their own questions and seeking answers. In other words, students develop competencies needed by professionals by becoming active participants in the learner-centered environment.

The ***methodological component*** of GameHub (fig. 5) in KNTU is based on the experimental realization of the innovative educational program through the development of learning modules for university courses and providing them with necessary educational recourses.

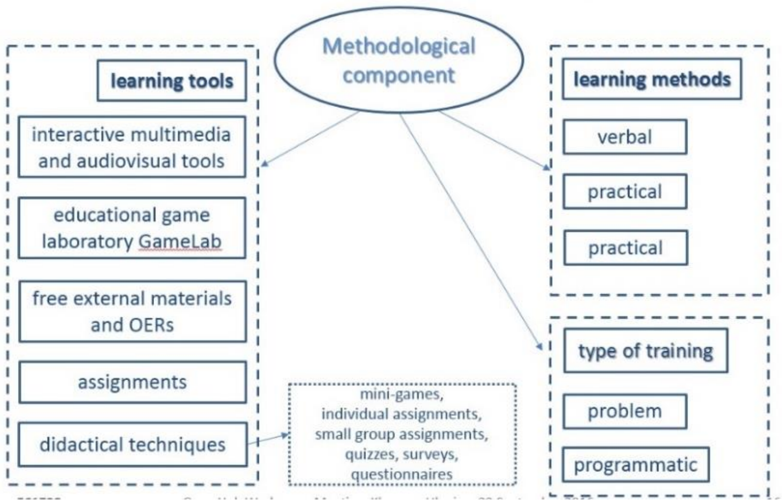

Fig. 5. The methodological component of KNTU GameHub

The educational program has module structure that covers all levels of necessary knowledge and skills, such as programming (Python, JavaScript, Java programming languages), startups, marketing.

Teachers, who passed appropriate training, have developed learning modules in the form of open educational recourses focused on using methods and forms of blended learning for students (trainees) on the base of learning game laboratory GameHub. The system of knowledge and skills provided by learning modules meet the developed profile of specialist's competencies.

The content of learning modules is provided through the verbal (lectures and consultations), scientific (presentations) and practical methods (laboratory practicals), as well as through the intensive use of the method of project execution (performance of individual and group (in small groups) problem tasks).

The base of an educational process aimed at developing the necessary competencies is problem-based learning through a certain system of methods and tools, which form creative thinking and cognitive ability of students (trainees) through the solving of problem-based tasks in the area of computer games development and game content creation. Cognitive situations, according to which a student has a lack of available knowledge for practical situational tasks solving, are designed for this purpose.

Using programmed learning elements allows splitting learning material into certain portions, which fit in with specific elements of understanding, and by virtue of a problem task in each portion provides for individualization of learning with appropriate feedback and self-control in task performance.

Programmed and problem-based learning have a theoretical form of lectures and consultations and practical form of individual tasks and work in small groups.

The ***technological component*** (fig.6) includes creating and maintaining Game Learning Laboratory (GameLab).

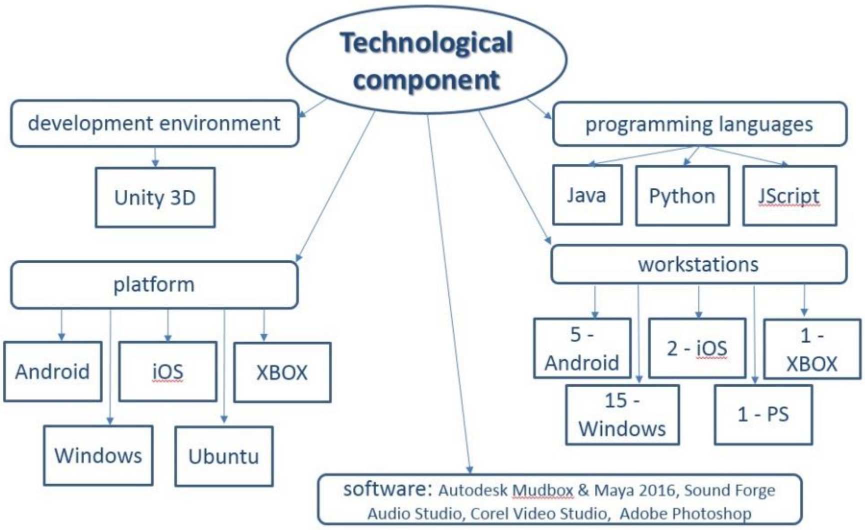

Fig. 6. The technological component of KNTU GameHub

The equipment and software of game learning laboratory GameLab meet the requirements of developed learning modules and will be used for learning and training the students, the trainees and teachers according to the educational program "Computer games development".

The ***informational component*** of the GameHub project in KNTU is aimed at wide dissemination of project results and involves providing information days, roundtables and job fairs.

The members of KNTU workgroup have organized information days for students that have been aimed at sharing the information about the goals of the project, as well as the opportunities for students in consequence of project realization in the university. The roundtables with potential employers and the students of Information Technologies department have been organized upon an initiative of the KNTU workgroup. Such roundtables are aimed at the development of partner relationships in University-IT-Enterprise format. One of such employers is Wezom web development agency that is a trustworthy website development and design company. Representatives of Wezom company have made aware the students of open vacancies in GI market, requirements to potential game developers. KNTU graduates who work for Wezom company have shared their working experience.

KNTU workgroup have also organized job fairs in Kherson Employment Centre, aimed at attracting certain target groups such as demobilized military, ATO veterans, resettlers from the Crimea and the eastern part of the Ukraine, as well as unemployed people to achieve professional competencies in the area of computer game design and development based on KNTU postgraduate centre.

The ***academic component*** of GameHub in KNTU (fig. 7) consists of:

1. an educational program on “Software engineering” specialty, “Computer games development” area of study, which is being renovated and improved permanently through the feedback from potential employers;
2. three learning modules, which are being developed by KNTU workgroup for implementation into the educational program on “Computer games development” area of study:
   - Computer games development using the Unity3d engine (Master’s degree, Bachelor degree),
   - Developing Game Web-applications (Master’s degree, Bachelor degree),
   - Network computer games development with Java (Bachelor degree);
3. Two learning modules which are being developed by KNTU workgroup for trainees of Institute of Postqualifying Education (including unemployment people, veterans of anti-terrorist operation):
   - Computer games development using the Unity3d engine,
   - Visual games programming;
4. Learning modules which are being developed by KNTU partners, including 15 learning modules for Bachelor or Master’s degree students and 5 learning modules for retraining of trainees, and which can be adapted for use in an educational program on “Computer games development” area of study in KNTU.

All learning modules have been created in accordance with the list of competencies resulting from the survey [7]. Each learning module has flexible structure and content, as well as its online version. Flexible module's structure imposes several versions of content for target groups of different levels of skills and knowledge. The online version of each module is meant for learners of any age returning to education after a period of work, unemployment or ATO-veterans.

As a result of the project piloting, which is being conducted at the present time, we have gathered positive feedback from employers. They confirm that the learning modules provide the competencies, which are essential for the success of the students in the digital GI market.

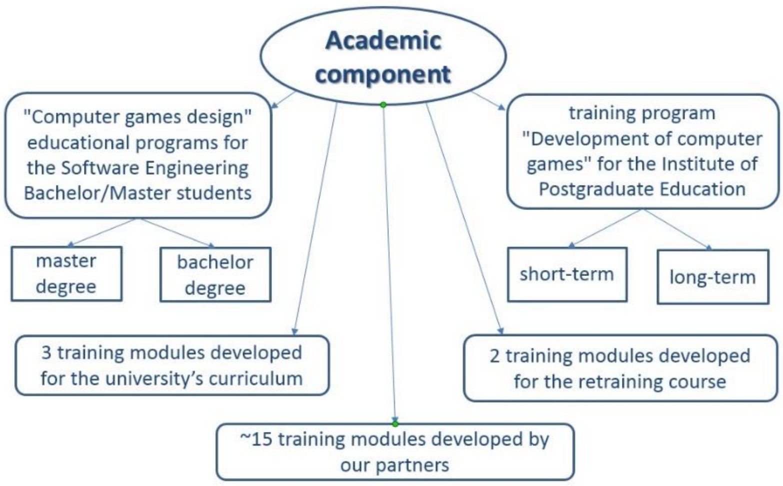

Fig. 7. The academic component of KNTU GameHub

5 Providing Project Sustainability

For providing GameHub sustainability [14,15] in KNTU some conditions have been created. They are as following (fig.8):

- GameHub learning laboratory provided with all necessary equipment and the staff for continued functioning is created;
- educational program on specialty "Program engineering", specialization "Computer games development" is developed;
- the agreements for collaboration with potential employers on the regional and national levels in terms of regular updates of competence profiles of specialists in the area of computer games development are signed;
- the agreement for collaboration with regional Employment Service is signed. The agreement provides for retraining and advanced training of unemployment people, ATO veterans and engineers, who are interested in the game development work in the area of game development, according to the Educational Program "Computer games development" in the Institute of Postqualifying Education of KNTU on the base of game learning laboratory GameLab;

- the learning modules, which constitute the Educational Program on specialization "Computer Games Development" are transformed and delivered on the base of the game learning laboratory GameLab into the open educational resource with the open public access;
- the game learning laboratory GameLab is used for delivery of course and graduate works by students and trainees, individual and scientific research tasks, for providing experiments by teachers and scientists while performing scientific and thesis research in the area of computer games development;
- the training, providing of consulting services in the area of computer games development on the base of the game learning laboratory GameLab for a wide variety of interested physical and juridic persons on the commercial basis are delivered;
- the GameHub infrastructure is used for the further implementation of innovative educational and scientific projects, related to computer games, their development technologies and gamification of education.

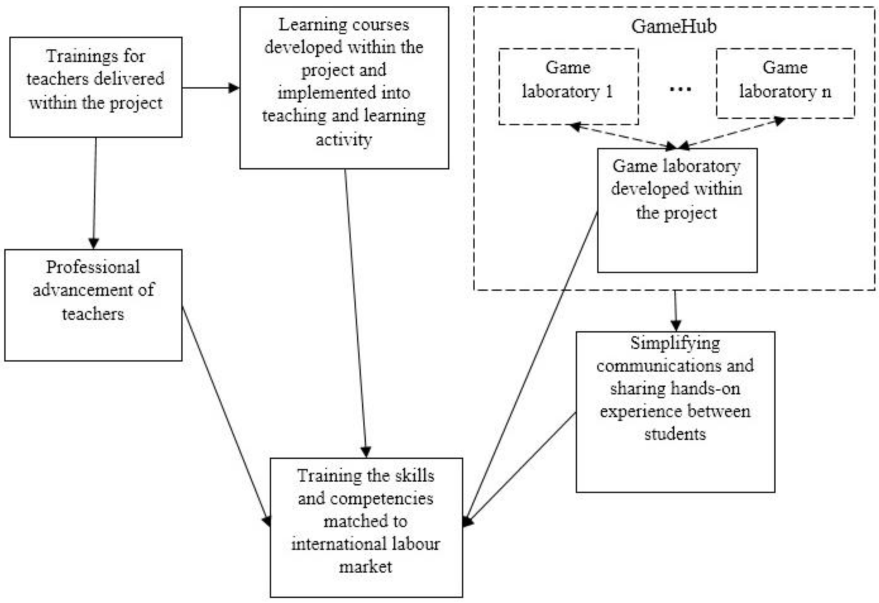

Fig. 8. Sustainability vision of GameHub project at KNTU

Within the GameHub project KNTU collaborates with eight IT companies specialized in computer game development. The closest collaboration is established with Wezom Company and MetaSoft Inc. We collaborated with them to create profiles of competencies needed by game studios using the questionnaires specially made for this purpose. 35 GI representatives were interviewed and questioned. The respondents evaluated common (core) and specific (professionally-oriented) knowledge and skills, which are necessary for the digital game design employees.

Based on the requirements of the employees, the work plan for the preparation of computer game developers and a set of necessary courses in KNTU has been developed.

A set of learning modules within a frame of GameHub project is developed in each Ukrainian partner-university. In KNTU they are as following: Developing Game Web-applications, Computer Games Development with Unity 3D, Network Computer Games Development with Java, Visual Game Programming. The courses are in the process of accreditation. All modules are connected into Hub and will be accessible not only for the Partner Universities but for all interested people (Fig.9).

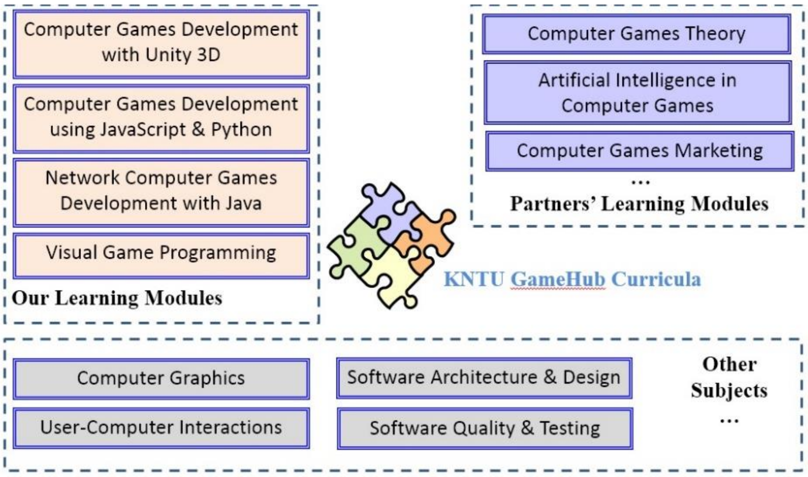

Fig. 9. KNTU Pilot Implementation: GameHub Curricula

To control and monitor the development of learning modules the pilot is being delivered (Fig.10). Approximately 180 University teachers, 500 students and 150 unemployed including ATO veterans are being trained. The final results of piloting are planned to be ready by the end of May, 2018.

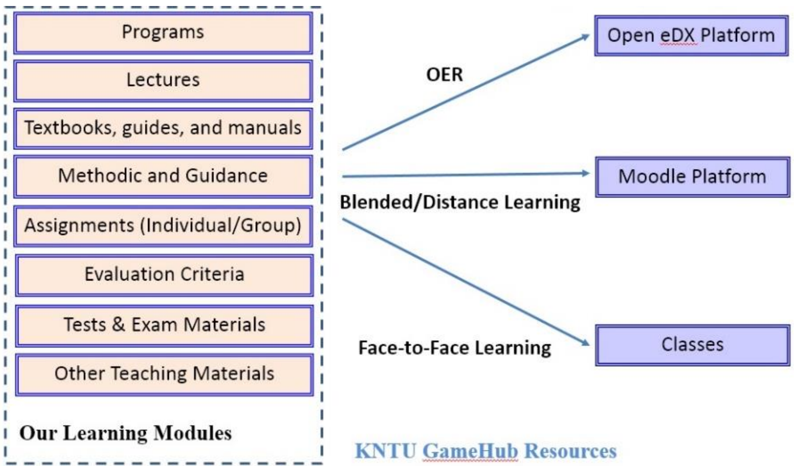

Fig. 10. KNTU Pilot Implementation: Preparing Stage

The implementation of the project allows preparing specialists in alignment with the demands of employees, which allow employees to save time for refresher courses and advances professional training of the graduates.

All Partner Universities are supposed to correct content of the modules based on the evaluation of using the modules in the educational process. This imposes realization of certain feedback loops, such as from industry expert after learning material preparation (Fig.11), from students after course finish, etc.

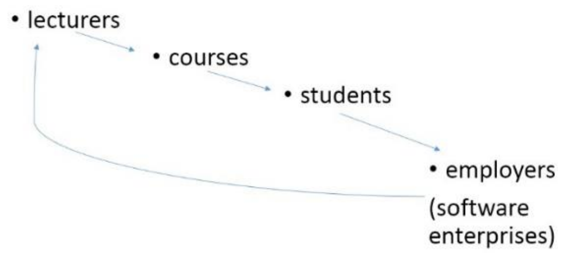

Fig. 11. KNTU GameHub educational feedback loop

Project sustainability is ensured by sustainable use of the game lab and GameHub learning materials as open educational resources within engineering curricula in the universities, as well as by incorporation the project results and outcomes in the professional training provided in education/training centers for unemployed people, ATO veterans, and other interested individuals.

The KNTU GameHub RoadMap is presented in Fig. 12. It shows the main stages of planned feedback from GI enterprises within the framework of university-enterprise cooperation.

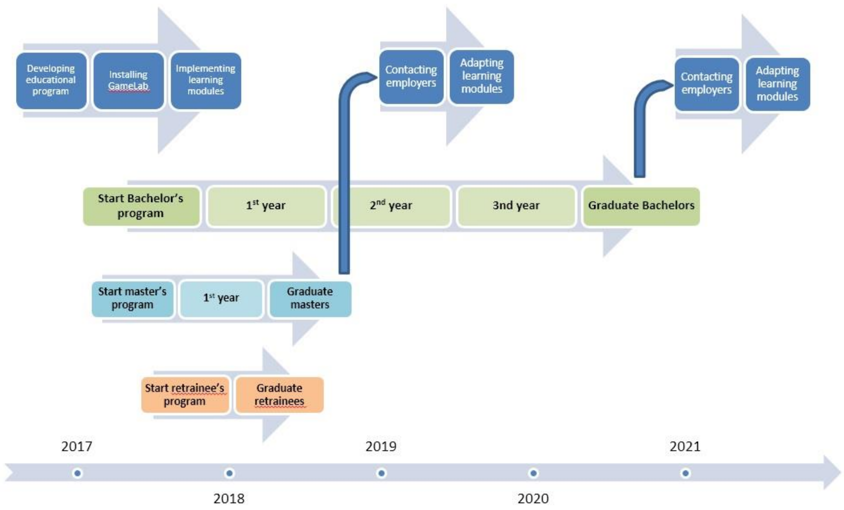

Fig. 12. KNTU GameHub RoadMap

In order to establish exploitation of the project results, the GameHub continuous to deliver and update the learning materials carried out by all trained teachers from Ukrainian Partner Universities during and after the project.

The mutually beneficial cooperation between Universities, small and medium-sized enterprises of the game business, and ATO veterans' associations established during the project will ensure GameHub further growth and exploitation fostering and investing into Ukrainian IT creative business sector.

6 Conclusions

The results of GameHub project will be helpful for Ukrainian higher education sector to respond to current and future education needs because mutually beneficial and sustainable university-enterprises cooperation can achieve a better match between competence profile of university graduates and those required by GI. This will provide graduates with high-level, employable skills, as well as the transferable skills that equip graduates for a fast-changing labor market. Ukrainian graduates will meet the requirements of the international labor market and can enhance the integration of Ukraine into European IT sector.

7 Acknowledgment

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Information and Technological Service for the Accompaniment of the Educational Process of People with Visual Impairments

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Abstract. The authors propose innovative approaches to the improvement of information technologies, methods and tools, which implement the formation of electronic library funds with specialized information products, integrating various types of information to provide information needs of people with disabilities. It is offered the new approaches to the formation of information resources and electronic libraries for this category of people promoting the processes of inclusive education. The processes of content preparation for providing convenient information and technological interaction of the blind with the information resources are analyzed, as well as the choice of the DAISY format (Digital Accessible Information System) for the creation of information products (audio books) with the use of flexible navigation mechanisms is substantiated. Moreover, it is proposed the classification of documents, which allows you to choose the levels of their structuring for effective transformation into DAISY format. The developed technology by authors is introduced and allows you to convert mathematical formulas of different complexity into a form that can be pronounced effectively by a synthesizer of the Ukrainian language.

The developed software and algorithmic means of sounding mathematical formulas in Ukrainian have given an opportunity to dub the Ukrainian technical texts with the help of a language synthesizer, fill DAISY books with technical content and convert the mathematical formulas into a text description. To convert the mathematical formulas presented in various versions of the MathML (presentation and semantic) records into an Ukrainian text, a special system of rules has been developed, which consists of rules for writing mathematical symbols, operators, general and specified expressions.

Keywords: DAISY format, electronic library, information resources for people with special needs.

1 Introduction

In the modern information society, a rethinking of traditional forms of information presentation is needed to the effective information support of the educational process of people with disabilities. The need of information resource formation in electronic libraries for this category of people has become especially relevant in connection with military actions taking place in Ukraine. Military men, who have been injured, after recovering, need to obtain "peaceful" occupations. But some of them got disabilities. This category of citizens needs special attention from the side of society. And learning processes require special approaches and specific information support, especially for visually impaired people.

The purpose of this paper is to present innovative methods and means of information and technological support of the educational process of people with visual impairment.

1.1 Analysis of the Research State

Increasingly, the need to expand the ability to provide information conveniently for people with special needs in different perceptual formats becomes relevant. The information technologies, methods and means that implement the resource formation of electronic libraries are developed and improved by specialized information products integrating different information to provide information needs of people with various physical disabilities. The research results on the information availability for blind users are reflected in the works of researchers such as Jeffrey P. Bigham, Meredith Ringel Morris, Yu Zhong, Samuel White [1] and others. Problems of creating information educational content are analyzed by Krapivenko A.V. [2] and Davydova E.V. [3] who investigate the problem of formation of effective multimedia information products. However, a comprehensive study of the peculiarities of the formation of information content for people with special needs has not been carried out yet.

1.2 Research Methods

The analysis of content preparation processes for the information and technological support of the educational process of the blind, conducted by the authors of the article, confirms the validity of the selection of the electronic book format for the blind, named DAISY format (Digital Accessible Information System). In this format books are convenient for the formation of an electronic library in terms of presentation of multimedia content. For the arrangement of the automated workplace of a blind user (AWP), modern special tools and technologies are used that provide convenient access of a blind user to information resources. To prepare the input data, the main provisions and methods of statistical analysis [4], classification [5, 6], and construction of decision trees are used, and to prepare the output audio content, it is used the method of transformation of the syntactic tree and the method of creating DAISY books in the Ukrainian language.

2 Electronic Libraries for People with Special Needs

Electronic libraries in the information society turn into convenient means for preserving information resources that provide information support and support for educational and social and communicative processes for people with special needs. An electronic library provides easy access to information resources online [7]. A characteristic set of basic features of an electronic library is its computer equipment, a digital way of recording information, technology of online access to information resources, etc. [8]. In addition to electronic documents, databases, user maps, hyperlink subsystems, other electronic information resources are the components of electronic libraries [9].

In this context, the information support of the educational process of people with special needs is the following:

- the use of specific forms of information representation for people with special needs, which in turn affects the features of the relevant information resource;
- the implementation of technological processes based on the algorithms of the information resource presentation created for each category of such users;
- the development of methodological recommendations for the information support implementation and information and technology support for the educational process of people with disabilities.

The term of electronic library for users with special needs means an information system designed to accumulate, structure and organize an array of electronic documents with an appropriate access system to provide a user with special needs with an integral toolkit for relevant and quick work with information resources in an easy format. In this case, special attention is paid to users with visual impairments. Modern technologies are capable of not only converting electronic documents to a convenient audio format for a blind user or dotted Braille font, but also provide the blind with a complete computerized workplace with all the possibilities, starting from work in text editors and ending with an access to the Internet or mastering skills on the computer.

When developing electronic libraries for people with special needs, specific methodological approaches are used, tested at creation and formation of traditional libraries. They have a reference search engine and a library and information resource. When forming an informational resource for blind users it is reasonable to accumulate electronic documents in the DAISY format.

3 DAISY Book in the Context of Information Support of the Learning Process

DAISY is an open international information and technology standard for access to multimedia content. The main developer of this standard is the DAISY Consortium, which interacted with a number of professional and civic organizations and formed the conceptual framework of the standard in close cooperation with leading staff of a number of libraries, scientists and user-practitioners. The science and technology innovation was directed to the main target group of vision-impaired users and users with other physical disabilities. The DAISY book is multimedia content with synchronization of text, audio and graphic information as well as advanced features for flexible navigation in it.

The core of DAISY technology is the effective tools for synchronizing text, graphics and audio based on the W3C recommendations, according to the people's needs that require providing a high-quality special way to information access.

The authors' analysis of the functional capabilities of the technologies that are fixed by the DAISY standard allows us to confirm that it can be used to provide a high quality support of a wide range of requirements inherent in database creation processes that contain multimedia information for the blind as it provides the audio content creation using mechanisms of flexible navigation. Users can listen to such book not only linearly; navigation tools provide an opportunity to make transitions from a section to a section, a subsection, a paragraph, a page. Documents in the DAISY format allow bookmarking of specific places in the text to re-listen to it and put voice tags.

A navigation map is imposed on the audiobook in a certain way and a "reader" can not only listen to the text, but also work with it: make bookmarks, notes, quick access to the necessary information. The DAISY books can be structured or unstructured in general. The decision on the structure of such book is taken when converting it into DAISY format.

The DAISY format books have the MP3 file archiving technique, which can hold up to 90 hours of audio tracks that can be listened to both on special playback devices and on the computer where the appropriate software is installed.

The DAISY format specification uses numerous cross-references among XHTML text files, MP3 audio recordings, SMIL synchronization files, and NCX navigation control. Extensible Hypertext Markup Language (XHTML) is an expanding hypertext markup language based on XML and features similar to HTML.

The DAISY book can consist of audio files, text files and images, or their combinations [10]. All DAISY books use a common set of file types, although some files are optional.

Almost all types of files in the DAISY format are based on XML [11]. The most important types of files that are part of DAISY books are batch, text content, image, audio file, synchronization, navigation management, resource, style presentation and transformations.

4 Technologies for Voice Recognition of Mathematical Expressions in the DAISY Format Books

For the organization of the educational process in the natural sciences, books with a formulaic component are required. For the transfer of mathematical expressions in books created in the DAISY format, the mathematical markup language MathML is used which is an XML element and is designed for use in XHTML documents.

Documents using the MathML language are not directly reproduced by the synthesizer. For the correct reproduction of such documents, various means are used to create different mathematical notations and text descriptions in different languages (except of Ukrainian). Most DAISY format playback players use the notation LAMBDA, LaTeX and Nemeth (Table 1).

Table 1. Encoding mathematical formulas in different notations

Formula encoding (notation)	**Example**
Traditional	$1+\sqrt{\frac{x^2-y^2}{x+y}(\mathrm{x}-\mathrm{y})}=0$
LaTeX	$1+\backslash sqrt\{\ (\ (x{*}{*}2-y{*}{*}2)\ /\ (x+y)\ )\ *\ (x-y)\ \}=0$
AMS	$1+(\ (\ (\ x{*}{*}2-y{*}{*}2)\ /\ (x+y)\ )\ *\ (x-y)\ )\ //2=0$
Nemeth	$\#1+>?X\wedge 2"-Y\wedge 2"/X+Y\#(X-Y)]\ \cdot K\ \ \#0$

Depending on the type of a player, it can voice mathematical formulas, alternative text (verbal description of a formula), work with the structure of a formula, etc. Our developed technology allows us to convert mathematical formulas of different complexity to the form which can further be expressed by the Ukrainian language synthesizer.

In order to automate the process of creation of teaching materials in Ukrainian in the form of DAISY books it was developed an applied programmed system for processing Ukrainian technical texts for people with visual impairments. The basis of the applied system is the modular structure, which makes it possible to implement it as separate functional modules.

The system consists of the components such as drivers of special equipment, basic software and special software. In Fig. 1, in the Special software block, the modules developed during this study are highlighted in the dotted lines:

- a module for processing files of various formats (allows a user to convert the format of an input book according to their needs);
- a module of keyword search in the text (provides search and text marking based on the structural features of a book, as well as mathematical formulas, descriptions of figures, etc.);
- an overlay navigation module on the book (this module is responsible for overlaying the selected navigation scheme on the input document and dividing it into separate parts);
- a module for converting a formula to a text description (provides the transformation of mathematical formulas and special characters into a text description in Ukrainian, in accordance with the rules developed by the transformation);

- a module for content layout and content storage (is responsible for preserving the structural parts of the book text in separate files, as well as giving an opportunity to voice them in Ukrainian).

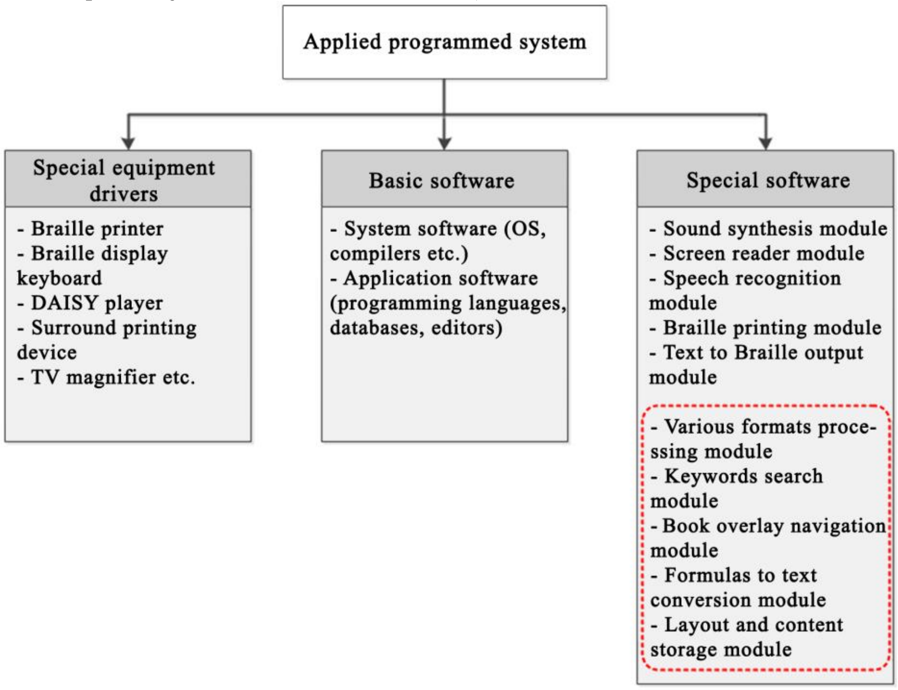


Fig. 1. Structural scheme of the applied system for processing Ukrainian technical texts for people with visual impairments

Each module has a finished functionality, working with an appropriate set of input parameters and output data.

The main function of the applied system for processing Ukrainian technical texts is the processing of information, namely collecting (receiving), processing, storing and displaying. The software interfaces of the system are designed for an inexperienced user, divided into many types of menus with a possibility to dub them with a reading system from the screen or output to the Braille line.

The program module of the applied program system for processing Ukrainian technical texts, which provides the transformation of mathematical formulas into an audio format, is developed by means of the language C # and available at: http://www.mathplay.ho.ua/

In the process of automated recording over information content, there are problems associated with the transformation and presentation of mathematical formulas.

Because of significant differences in constructing and reading mathematical formulas in different languages, it is impossible to adapt English-language systems such as MathPlayer, Dolphin EasyReader, MathSpeak due to differences in the construction of sentences, besides, the indicated software is licensed rather than in open source. It causes precisely to develop an applied programmatic system for the sounding of Ukrainian technical texts with a formulaic component.

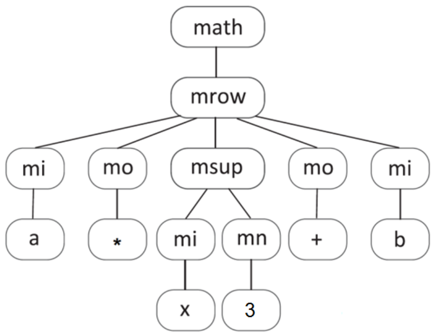
We have not found publications in Ukrainian or Russian that would contain rules for reading mathematical formulas or methods for decomposing mathematical formulas, but there are some publications in English [12, 13]. These publications are basis for the development of rules for decomposition of the mathematical formula. To convert MathML to a text, a transformation model for a syntax tree is used, based on the rules described in these publications.

Taking into account the prevalence of the MathML language, its tree structure and the availability of means for converting formulas in different formats to the MathML language, we consider appropriately it to use for internal formula recording. The MathML language is selected as an intermediate one for the development of means for sounding formulas.

The formula written in the MathML language has a tree structure, which makes it possible to describe the semantics of the mathematical expression unambiguously in the information system. Writing a mathematical formula in the MathML language can be represented as a tree whose vertices are operations and operands. In this case, each node in the tree corresponds to a particular layout, and its branches or descendants are subexpressions. In other words, it is a graphical representation of a mathematical formula that shows how exactly the MathML tags should be inserted in each other for the correct representation of a given mathematical expression on the screen (Fig. 2).

```
<math>
  <mrow>
    <mi>a</mi><mo>*</mo>
      <msup>
        <mi>x</mi><mn>3</mn>
      </msup>
    <mo>+</mo><mi>b</mi>
  </mrow>
</math>
```

a)



b)

Fig. 2. Formula a * x ^ 3 + b in the language MathML (a), its image in the form of a tree (b)

For the transformation of the mathematical formulas presented in various versions of the MathML (presentation and semantic) record, a special system of rules has been developed for the text in Ukrainian. The system consists of rules for writing mathematical symbols, operators, general and specified expressions.

Rules for specified expressions are necessary in cases when the reading result depends not only on the tree node, but also on the value of its descendant. For example, x^2 should be read the “x square”, and not “xx in power two”. The rules are designed so that the original text could be read with the synthesizer of the Ukrainian language.

The developed rules for the conversion of the mathematical formula are divided into four groups:

1. Character conversion rules. In accordance with these rules, the MathPlay program is designed to convert formula symbols recorded in the MathML language, for example, “x” – “x”, “a” – “a”, “b” – “b”, “c” – “c”, “dt” – “dt”, “\u221E” – “infinity”, etc.

2. Operator conversion rules. With the help of these rules, formulas are transformed, for example, “-“ or “minus” – “minus”, “+” or “plus” – “plus”, “=” or “eq” – “equal”, “times” – “multiply”, “±” – “plus minus”, “(“ – “open a bracket”, “)” – “close a bracket”, “\ u222B” – “integral”, etc.

3. Common expression conversion rules. These rules are used in the following cases:

- raise to the power: “msup” – “*number_1* is raised to the power *number_2*”;
- raise to the power “power” – “*number_1* is raised to the power *number_2*”;
- division: “mfrac” – “*number_1* is divided by *number_2*”;
- extraction of the square root: “msqrt” – “root square from *number_1*”;
- extraction of the root of n-th power: “root” – “root of power *number_1* from *number_2*” etc.

4. Specified expression conversion rules. These rules are used in the following cases:

- “power 2” – “square”;
- “power 3” – “cube”;
- “root 3” – “root cubic from *number_1*”;
- “apply plus” – “*number_1* plus *number_2*” etc.

5 Analysis of the Results of the work of the Applied Program System for Processing Ukrainian Technical Texts

To test the results of the applied programmed system for processing Ukrainian technical texts, five groups of experiments were carried out to convert mathematical formulas presented in various formats into the mathematical markup language MathML, as well as dubbing and perception of the obtained formulas by blind users by ear (Fig. 3).

For experiments on the convertion of formulas into MathML language, a random set of mathematical formulas of various complexity is taken, from simple ones as $\sqrt{a+b} = 6$, to complex ones as $f(x) = a_0 + \sum_{n=1}^{\infty}(a_n \cos\frac{n\pi x}{L} + b_n \sin\frac{n\pi x}{L})$.

The test base for the first four groups of experiments contained 100 formulas, with 25 formulas per group. Among them, 20 formulas are simple arithmetic expressions, another 20 are trigonometric expressions, 20 ones are integrals and derivatives, 20 are linear algebra formulas and 20 are series, borders, etc.

During the experiments, free software (UkrVox, Ttm, OpenOffice, etc.) and demo versions of commercial products (GrindEQ Math Utilities, InftyReader, MathType, etc.) were used.

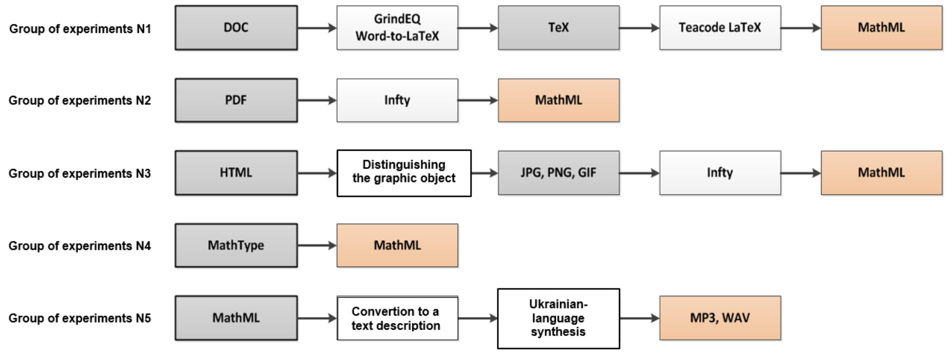


Fig. 3. Conducting experimental research

The group of experiments № 1 (*.DOC → «GrindEQ Math» → TeX → Teacode Latex → MathML).

The first group of experiments was to convert the formula set into the MathML language written as a Microsoft Word document format.

The group of experiments № 2 (*.PDF → Infty → MathML).

The second group of experiments was to convert the formula set into the MathML language written in the Adobe Reader, * .PDF format.

The group of experiments № 3 (*.HTML → selecting graphic objects → JPG, PNG, GIF → Infty → MathML).

The third group of experiments was to convert a formula set into a MathML language written as a * .HTML web page.

The group of experiments № 4 (MathType → MathML).

The fourth group of experiments was to convert a formula set written with MathType into the MathML language and save the copied formula in a text editor with * .MML extension.

According to the results of the conducted experiment, the greatest errors and incorrectness were when the mathematical formulas were recognized by means of the Infty program and converted to the mathematical markup language MathML. Only 21 formulas were correctly recognized from the 50 formulas of different complexity (25 formulas from the experiment group № 2 and 25 formulas from the experiment group № 3). Thus, Infty software, due to the imperfection of the recognition means, provides only 42% of the accuracy of recognition processes of complicated formulas. For example, the formula of medium complexity $\sqrt[3]{(b+c)} = a$ was recognized wrongly, with two errors: 3√ (b + c) = Ω.

In parallel, the processes of converting the formulas to the MathML language by technologies selected for the first and fourth groups of experiments gave the correct result on 100%, and non-significant inaccuracies were recorded for the second and the third groups.

The group of experiments № 5 (dubbing the formulas in Ukrainian transformed into MathML language).

For this group of experiments, 150 different formulas were taken during the research. All formulas are divided into groups: equations (rational, square, linear), inequalities, identical expressions, fractional expressions and functions. Each group included formulas of various complexity.

Experiments were consisted of the correct perception by ear of the mathematical formula dubbing by the developed MathPlay program and recorded it in the notebook during the listening.

Performing experiments on simple formulas (250 formulas), five respondents made two errors during playback, making up 0.8% of the total number of records. According to the calculations of experiments, respondents made 11 mistakes on formulas of average complexity with the same number of formulas, that is, 4.4% of the total number of records. The third part of the experiments over complex formulas showed the following result: 44 errors, or 17.2% of the total number of records.

Consequently, the MathPlay program of dubbing mathematical formulas and symbols has produced a good result. The program correctly reproduces 693 out of 750 records (92.5%) for formulas of various complexity.

According to the participants of the experiments, the main difficulty during the experiments was the understanding of the synthesized voice and high speed of reproduction. In addition, the overall result was influenced by the formula complexity.

6 Interface of a Blind User Interaction with an Electronic Library

One of the most important tasks faced by the developers of the library information and technology service for people with visual impairments is a solution of the issues of the multimedia structured content formation for a convenient interaction of the blind with library services by means of computer.

As the main purpose of developing such system is to maximize the automation of the interaction between a blind reader and an electronic library, the proposed model of the system will provide such interaction by means of an automated workplace through the program interface with special way of input and output information.

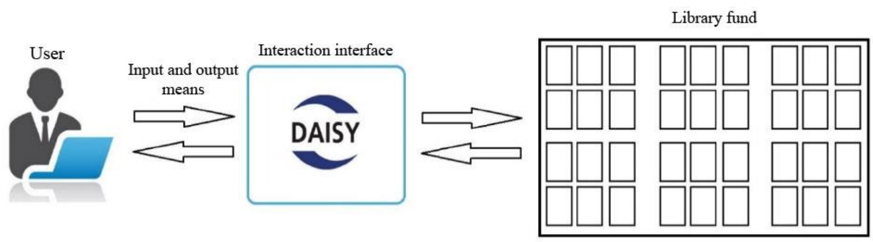


Fig. 4. Interaction process of the blind user and the electronic library

In the Fig. 4 it is shown a block diagram of the interaction process of a blind user with an electronic library. With the help of a specially equipped automated workplace and software interface, the blind user can access to library resources and find a necessary book for reading.

The general scheme of the equipped automated workplace for a blind user consists of basic and special technical means, software, various organizational measures. In addition to working on a computer, a person with visual impairment can receive information from additional technical devices such as a TV, a mobile phone, audio players and magnifying devices, etc. This automated workplace allows synchronizing these devices with a computer for convenient and fast operation.

The system of interaction of a blind user with a computer can be supplemented by additional software and hardware, in accordance with the needs of the blind, in particular, for working with math, graphic objects and musical instruments.

7 Conclusion

The developed software and algorithmic means of sounding mathematical formulas in the Ukrainian language gave an opportunity to voice the technical texts of the Ukrainian language with the help of a language synthesizer, fill DAISY books with technical content and convert mathematical formulas into a text description. An integral part of the soundtrack is a special system of rules, which ensures the correct conversion of the mathematical formulas presented in various versions of the MathML record. The system of rules consists of algorithms for writing mathematical symbols, operators as well as general and specified expressions.

The developed applied programmed system for processing Ukrainian technical texts provides automation of processes for the creation of adapted teaching materials containing mathematical formulas for the needs of a blind user.

Experiments on the correctness of automatic sounding of mathematical formulas carried out during the testing of the applied programmed system for processing Ukrainian technical texts allow us to assert that the developed software product provides a clear dubbing in Ukrainian of 92.5% of the formulas of various complexity. There are no computer technological and methodological analogues of this software product in Ukraine. The presented workings are technologically commensurate with the world's achievements in the field of cutting-edge information technology focused on people with special needs. The applied program system for processing Ukrainian technical texts is used to accompany the educational processes of blind pupils and students.

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Informatisation of School Education in Ukraine under Globalization and Europeanization

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Abstract. The article describes the tendency of informatisation of school education in Ukraine during the time of independence. Based on the analysis of legislative and strategic documents defining the development of Ukrainian education, the movement is open starting from the idea of introducing information resources into education in the early 90's of the 20-th century to complex informatisation with the purpose of formation of information space, ICT-competent young generation at the present. Under conditions of the European choice of Ukraine and the Europeanization of Ukrainian education, the importance of the study of the experience of the European countries and the EU on the development of ICT-oriented education have been proved. The strategic documents of the EU in the field of education that emphasize the importance of digital education in the information society are analyzed, and its priority in educational strategies has been proved. The conclusion is made about the prospects of European experience for Ukraine and, at the same time, attention is drawn to the aspects that require further development at the strategic level.

Keywords: Informatisation, School education, Ukraine.

1 Introduction

After proclamation of Ukraine's independence in 1991 its further development as a state foresaw the reform of education aimed at creating a system to respond new democratic realities. The first educational legislative document – the Law of Ukraine "On Education" (1991) – was aimed at the decomunization of education, upbringing of the younger generation in the spirit of national and universal values, giving priority to the Ukrainian language [25]. At the same time, the wave of the information revolution at the end of the 20-th century activated new challenges at the global level, which caused the need to respond by the Ukrainian education by introducing appropriate changes primarily to the legislative and regulatory base by synchronizing with the educational strategies of the countries of the world. The strategic documents in the area of education in Ukraine – the State National Program "Education" (Ukraine 21-st Century) (1993) [28], National Doctrine of Education Development (2002) [14], National Strategy for the Development of Education in Ukraine until 2021 (2013) [16], Concept “New Ukrainian School” (2016) [23] – adopted during the twenty five years of independence of Ukraine, reflect the gradual movement of the Ukrainian school education in the direction of informatisation. The new Law of Ukraine “On Education” (2017) [26] positions the national education as information-based one, harmonizes its development with the development of EU countries that consider informatisation of education as one of the priorities in the strategic documents. These are strategic education program “Education and Training 2020” (2009), the European Commission’s “Rethinking Education: Investing in skills for better socio-economic outcomes” (2012) program and others.

The research results outlined in this article are obtained in the framework of the research work of the Department of Comparative Education of the Institute of Pedagogy of the National Academy of Educational Sciences of Ukraine on the problem of educational transformations in the EU countries and the USA.

The purpose of this article is to analyze the dynamics of informatisation of school education in Ukraine under globalization and Europeanization at the level of legislative and strategic documents. In this article we understand the informatisation as a process of transforming national school education in a broad sense into the information paradigm.

2 Literature Review

The problem of informatisation of education, application of information and communication technologies (ICT) in the educational process is the subject of research of many Ukrainian scholars. For instance, V. Bykov, R. Gurevich, M. Kademii, L. Nakonechna, L. Petrova, S. Sysoeva study the development of the conceptual apparatus on informatisation of education; V. Bespalko, L. Belousova, V. Zabolotnyi, T. Nosenko – didactic and methodical aspects of the application of ICT in the e-learning process; V. Andrushchenko, A. Kudina – formation of modern information and educational environment based on introduction of innovative technologies for teaching; S. Rakova, Y. Ramsky, A. Yurchenko – competence approach and ICT; Dzyuba, M. Zhaldak, S. Kizim, S. Loboda; I. Vorotnikov, A. Kocharyan, N. Morse, S. Petrenko – peculiarities of formation of information competence of future teachers by means of ICT; T. Tarnavska, O. Torubara, V. Umanets -– application of ICT in the educational process of higher educational institutions [2].

The works of the Ukrainian scholars working in the area of comparative education with attention to the ICT aspects in education are of special interest for this research. In particular, A. Gurzhiy and O. Ovcharuk in the paper “Discussion aspects of information and communication competence: international approaches and Ukrainian perspectives” (2013) raise an issue of understanding the informational-communication competence in international and national educational dimensions. O. Bilous, O. Grytsenchuk, I. Ivanyuk, O. Kravchyna, M. Leschenko, I. Malitska, N. Morse, O. Ovcharuk, D. Rozhdestvenskaa, N. Soroko, L. Tymchuk, V. Tkachenko, M. Shinenko, A. Yatsyshyn in the guidebook “Formation of Informational-Communication Competences in the Context of European Integration Processes of

Creation of Information Educational Space" (2014) reveal general approaches to the formation of informational-communication competence of pupils in the European countries under the conditions of informational educational environment. The guidebook "Assessment of informational-communication competence of pupils and teachers under European integration processes in education" (O. Ovcharuk, O. Hrytsenchuk, I. Ivanyuk, O. Kravchyna, M. Leshchenko, I. Malytzkaya, N. Soroko, L Tymchuk, 2017) offers an overview of the practice of assessing the informational-communication competence of pupils, teachers and managers of general education institutions in the European countries [9; 1].

3 Results of the Research

In the Encyclopedia of Education (2008) informatisation of education is understood as an set of interrelated organizational, legal, socio-economic, educational, methodological, scientific and technical, production and management processes aimed at satisfying the information, computing and telecommunication needs associated with the possibilities of methods and means of ICT of the participants of educational process, as well as those who manage and provide this process [8]. V. Bykov, the author of the article on the informatisation of education in the Encyclopedia states that the informatisation of education involves wide and effective implementation and use of ICT in the implementation of educational, scientific and management functions inherent to the educational field, as well as informatisation of education that significantly affects the content, organizational forms and teaching methods [8].

The conducted analysis of the documents showed that the issue of informatisation of education and the introduction of information technologies were already raised in the first strategy of national education development – the State National Program "Education" ("Ukraine XXI Century") (1993). Informatisation of secondary, vocational and higher education is considered as a prerequisite for its reformation [28].

The Concept of the National Program of Informatisation (1998) became an important reference point for informatisation of the education of Ukraine. Here the informatisation is positioned as a set of interrelated organizational, legal, political, socio-economic, scientific and technical, productive processes aimed at creating conditions to satisfy the information needs, realizing the rights of citizens and society on the basis of creation, development and use of information systems, networks, resources and information technologies created on the basis of application of modern computing and communication equipment. Informatisation of education is considered here as an instrument for the formation and development of the intellectual potential of the nation, the improvement of the forms and content of the educational process, the introduction of computer teaching and testing methods. The results of informatisation of education in the document are: development of information culture of a person (computer education); development of content, methods and means of learning to the level of world standards; shortening the term and improving the quality of education and training at all levels; integration of educational, research and production activities; improvement of education management; staffing of all areas of informatisation of

Ukraine through specialization and intensification of training of relevant specialists [18].

The need of informatisation of education as a complex of measures aimed at modernizing Ukrainian education, its compliance with the best European and world standards was proclaimed in the innovative at that time strategic document in education - the National Doctrine of Education Development (2002). The document responded to the challenges of globalization, transition to the information society. The introduction of information technologies has been declared as one of the priorities of the development of national education. The introduction of modern ICT is associated with further improvement of the educational process, accessibility and efficiency of education, training of the younger generation for life in the information society. This is planned to be achieved through gradual informatisation of the education system aimed at satisfying the educational information and communication needs of the participants in the educational process; the introduction of distance learning with the use of ICT in the educational process along with traditional means; the development of individual modular curricula of different levels of complexity depending on specific needs, as well as the provision of electronic textbooks; the creation of an industry of modern teaching methods that correspond to the world scientific and technical level being an important prerequisite for the implementation of effective strategies for the achievement of educational goals.

The National Doctrine of Education Development states that the state supports the process of informatisation of education, the use of ICT in the education system; promotes the provision of educational institutions with computers, modern learning tools, and the creation of global information and education networks [14].

Under conditions of the rapid dissemination of ICTs in all spheres of human life, the Ukrainian state has approved a number of important documents proclaiming the task to build an information society. Thus, the Law of Ukraine "On the Basic Principles of the Development of the Information Society in Ukraine for 2007-2015" (2007) defines the tasks, objectives and directions of the development of the information society.

In the document the main strategic goal of the development of the information society in Ukraine is the provision of computer and informational literacy of the population, first of all through the creation of a system of education oriented towards the use of the newest ICTs in the formation of an all-round personality; as well as the development of the national information infrastructure and its integration with the global infrastructure.

Information society in Ukraine is considered as one in which every person widely uses modern ICT opportunities for the creation of information and knowledge, uses and exchanges them, produces goods and provides services, fully realizing their potential, increasing the quality of their lives and contributing to the country's sustainable development based on the purposes and principles proclaimed by the UNESCO Declaration of Principles worked out at the highest level World Summits on the information society, i.e. the Geneva Declaration of Principles "Building the Information Society: A Global Task in the New Millennium" (2003) and Tunisia Program for the Information Society (2005).

Under this context it is important that in conjunction with the development of information infrastructure, the state proclaims the goal of ensuring computer and information literacy of the population, first of all through the creation of a system of education focused on the use of the newest ICTs in the formation of an all-round personality. In order to accelerate the ICT introduction into the secondary education institutions the state target program "One Hundred Percent" was launched in 2011 aimed at ICT implementation into the educational process for the period until the year 2015. The program provided the provision of comprehensive educational institutions with ICT, the creation of an open network of educational resources, updating the content, forms and methods of teaching computer science, training and improvement of teachers' qualifications [29].

At the beginning of the 21-st century under intensification of globalization, deep and dynamic penetration of ICT into all areas of life the countries of the world intensified the transition from the economy based on a fuel and raw materials to the knowledge-based economy in order to reduce threats to national security, increase social well-being of societies, attract citizens to all the benefits of the information society.

Ukraine adopts the Strategy for the Development of the Information Society in Ukraine (2013) in order to accelerate the development of the information society. The main directions of the Strategy implementation are the following: development of such spheres of public life as information infrastructure, information security, e-economy, e-governance, e-democracy, e-culture, e-medicine, e-education. The last one is seen as a tool for learning, upbringing, training for work in the information society. Within this goal, it was planned the following:

- ensuring the gradual informatisation of the education system aimed at satisfying the educational information and communication needs of the participants of the educational process;
- formation and implementation of informational educational environment of the education system;
- development of individual modular curricula of different levels depending on concrete needs, as well as the production of electronic textbooks and encyclopedias;
- creation of information system supporting the educational process, information and analytical support
- system in the field of management of educational institutions, information and technological support of education monitoring;
- provision of full-scale educational institutions with computer complexes and multimedia equipment;
- development of a network of electronic libraries at all educational levels;
- creation of a system of distance learning, including people with disabilities and children in long-term treatment, and ensuring the effective implementation and use of ICT at all educational levels of all forms of education;
- ensuring the educational process by means of ICT, as well as access of educational institutions to the world
- information resources;

- creation of an open network of educational resources;
- creation of the national scientific and educational space, which will be based on the unification of various national multi-purpose informational-communication systems;
- development of methodological support in the use of computer multimedia technologies in the process of teaching subjects and disciplines;
- improvement of a curriculum, opening of new specialties from the latest ICTs, the implementation of the principle of “life-long education”;
- providing free access to ICT and information resources, especially in rural areas and remote settlements;
- raising the level of computer literacy of the population;
- creation the conditions for mastering the computer literacy of all graduates of schools within the next five years;
- provision of all educational institutions with the broadband access to international scientific and educational networks and the Internet [16].

The National Strategy of the Development of Education in Ukraine for the period up to 2021, approved in the same 2013 year, noted the slow informatisation of the education system and the introduction of ICT into the educational process. Considering this, informatisation is proclaimed as one of the strategic directions of the state policy in the field of education. In the document, informatisation of education is positioned as implementation of modern ICTs, which provide improvement of the educational process, accessibility and efficiency of education, training the younger generation for life in the information society. The Strategy actually repeats the measures planned in the Strategy of the Information Society Development in Ukraine (2013). It is aimed at equipping educational institutions with computer technology and access to the Internet, as well as global information resources, implementing information education environment into the education system, creating an information system supporting the educational process and providing electronic textbooks [16]. Consequently, the National Strategy for the Development of Education in Ukraine for the period up to 2021 forms the system of education focused on the use of ICT at the state level.

The concept of the implementation of state policy in the area of reforming general secondary education “New Ukrainian School” for the period up to 2029 (2016) continues to consider the education system as an ICT-based one, linking the success of the reform of the Ukrainian school with the speed of ICT implementation into education. The document states that the introduction of ICT in education should be shifted from one-time projects to a system process covering all types of activities. The result should be the formation of key competencies of pupils, which means that ICT significantly expands the capabilities of a teacher, optimize management processes, thus forming important for our century technological competences of pupils, information and digital competence, which means the confident and critical use of ICTs for the creation, retrieval, processing, exchange of information at work, in the public space and in private communication; possession of information and media literacy, the basics of programming, algorithmic thinking, database skills, internet security and cyber security; understanding the ethics of working with information [23].

Information and digital competence as one of ten peoples key competencies to be formed at the end of secondary schooling is officially approved by the new Law of Ukraine "On Education" in 2017 [26].

Thus, as evidenced by the analysis of legislative and strategic documents, the national education during the years of independence has gone from introducing information resources to comprehensive informatisation aimed at forming the information society in which the population and, above all, young people have ICT competence, confidently using ICT for work and life.

As stated in the National Report on the State and Prospects of Education Development in Ukraine (2016) the main results in the area are the following:

- gradual informatisation of the education system aimed at satisfying the educational information and communication needs of the participants of the educational process;
- formation and implementation of informational educational environment of the education system;
- formation of a computer-technological platform for open education at all levels – from preschool to postgraduate and life-long education based on usage of cloud computing technologies;
- improvement of compute technical equipment of educational institutions; cabinets, laboratories, workshops, libraries;
- upgrading teaching technologies, methodical support and content of distance and e-learning on the basis of ICT;
- introduction of new forms of organization of educational process, forms and methods of teaching (e-learning, mobile learning, smart learning, STEM education, open online courses, etc.) based on cloud oriented technologies, Web 2.0 technologies, electronic social media services);
- introduction of open educational systems based on electronic scientific and educational resources, science-based open source databases, systems and electronic libraries;
- development of complex of scientific researches on informatisation of education;
- formation and development of information culture and ICT-competencies [15].

EU MASTIS project can be good example of Ukraine's improvements on ICT in high schools, i.e. Simon Kuznets Kharkiv National University of Economics, Ukraine, National Technical University of Ukraine "KPI", Ukraine; Lviv Polytechnic National University, Ukraine, Vinnytsia National Technical University, Ukraine, Kherson State University, Ukraine, National Technical University "Kharkiv Polytechnic Institute", Ukraine under auspice of the Ministry of Education and Science of Ukraine [12]. The Project goals are to improve Master Program in Information Systems according to the requirements of business; to modernize the current Degree Profile and curricula in Information Systems; to develop innovative academic environment for Master program of Informational Systems as a platform for training/retraining, PhD, LLL; to modernize labs infrastructure for Information Systems.

However, according to the statistics of the Ministry of Education and Science of Ukraine and the State Statistic Service of Ukraine, in Ukraine the number of students per school computer in 2011 was 27.0, in 2012 – 25.0, in 2013 – 21.0, in 2014 – 17.0, and in 2015 – 16.0 [13]. At the same time, according to the OECD Report "Students, Computers and Learning. Making the Connection"(2015) in 2012 in Australia the number of students per school computer was 0.9, in the UK – 1.4, in the Czech Republic – 1.6, in the USA – 1.8, in Lithuania – 1.9, in Estonia – 2.1, in France – 2.9, in Finland – 3.1, in Poland – 4.0 [17, c. 20].

Data from the International Study of Measuring the Information Society Report (2015) testify that Ukraine has been lagging behind the developed countries regarding the development of the information society, despite the existing potential and opportunities [30]. This conclusion corresponds to the findings of the Global Information Technology Report 2016 according to which Ukraine ranks 64-th among 139 countries according to the Networked Readiness Index 2016 [31]. And this is a call for action, especially within the framework of the Association Agreement between Ukraine and the EU (2014).

The Association Agreement has taken the development of the information society in Ukraine to the new level intensifying the process of its synchronization with the EU standards, integration into the European digital space. Chapter 14 "Information Society" of the Agreement foresees the strengthening cooperation between the parties on the development of the information society through the provision of universal access to ICT [24]. The cooperation aims at implementing national information society strategies, developing a comprehensive regulatory framework for electronic communications and expanding Ukraine's participation in EU ICT research activities.

The strategic education and training program – Education and Training 2020 (2009) underlines the importance of innovations for building the most competitive and dynamic knowledge-based economy in the world [5].

The EU Strategy Paper "Rethinking Education: Investing in skills for better socio-economic outcomes" (2012) was the response of the European Community to new globalization and internal challenges within the EU's borders in the second decade of the 21-st century. In particular it emphasizes that modern, knowledge-based economies require people with higher and more relevant skills especially under on-going digital revolution. At the same time digital revolution brings important opportunities for education, i.e. it offers unprecedented opportunities to improve quality, access and equity in education and training; it is a key lever for more effective learning and to reducing barriers to education, in particular social barriers. Individuals can learn anywhere, at any time, following flexible and individualized pathways.

At the same time, even under the most favorable conditions for acquiring digital competences within the EU borders, according to EU statistics around 40% of the EU population has an insufficient level of digital skills; 32% of the EU workforce have insufficient digital skills, with 13% assessed as having none at all; 42% of the citizens with no computer skills are inactive in the labour market in 2015. As a result, many citizens lack the ability to explore the full potential of digital technologies in their everyday lives.

The adoption of documents that transform the education system into the digital basis was the answer to the above mentioned challenges. The architecture of digital-oriented education comprises digital competence frameworks for citizens (DigComp), educators (DigCompEdu), educational organisations (DigCompOrg) and consumers (DigCompConsumers). A framework for opening up higher education institutions (OpenEdu) was adopted in 2016, along with a competence framework for entrepreneurship (EntreComp). Some of these frameworks are accompanied by (self-) assessment instruments.

The competence strategy in education within EU in education is based on the European Reference Framework for Key Competences for Lifelong Learning, approved by the European Parliament and the European Council in 2006 [4]. The document identifies eight key competencies, including digital competence, which is defined as the one which involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet.

It should be noted that the EU's approach to the definition of competences and digital competence in particular was the basis for developing the concept of competency education in Ukraine and the interpretation of digital competence (see Table 1).

Table 1. Digital Competence in the European Reference Framework of Key Competences for Lifelong Learning (2006) and in the "New Ukrainian School" Concept (2016).

European Reference Framework of Key Competences for Lifelong Learning (2006)	**"New Ukrainian School" Concept (2016).**
Digital competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet	Information and digital competence means the confident and critical use of ICTs for the creation, retrieval, processing, exchange of information at work, in public space and in private communication; possession the information and media literacy, the basics of programming, algorithmic thinking, database skills, Internet security and cyber security; understanding the ethics of working with information

The European Digital Competence Framework for Citizens and a related self-assessment tool in 2015 – known as DigComp – was adopted by the European Commission in 2015. DigComp is a common reference framework that sets out 21 competences, grouped in 5 key areas, to describe what it means to be a digitally competent personality:

1. Information and data literacy: to articulate information needs, to locate and retrieve digital data, information and content; to judge the relevance of the source and its content; to store, manage, and organize digital data, information and content.

2. Communication and collaboration: to interact, communicate and collaborate through digital technologies while being aware of cultural and generational diversity; to participate in society through public and private digital services and participatory citizenship; to manage one's digital identity and reputation.
3. Digital content creation: to create and edit digital content; to improve and integrate information and content into an existing body of knowledge while understanding how copyright and licenses are to be applied; to know how to give understandable instructions for a computer system.
4. Safety: to protect devices, content, personal data and privacy in digital environments; to protect physical and psychological health, and to be aware of digital technologies for social well-being and social inclusion; to be aware of the environmental impact of digital technologies and their use.
5. Problem solving: to identify needs and problems, and to resolve conceptual problems and problem situations in digital environments; to use digital tools to innovate processes and products; to keep up-to-date with the digital evolution [6].

Digital Competence of Educators (DigCompEdu) published in 2017 is no less important [7]. Six DigCompEdu areas focus on different aspects of educators' professional activities:

- Area 1: Professional Engagement Using digital technologies for communication, collaboration and professional development.
- Area 2: Digital Resources Sourcing, creating and sharing digital resources.
- Area 3: Teaching and Learning Managing and orchestrating the use of digital technologies in teaching and learning.
- Area 4: Assessment Using digital technologies and strategies to enhance assessment.
- Area 5: Empowering Learners Using digital technologies to enhance inclusion, personalization and learners' active engagement.
- Area 6: Facilitating Learners' Digital Competence Enabling learners to creatively and responsibly use digital technologies for information, communication, content creation, wellbeing and problem-solving.

A new strategic initiative aimed at further building the information society in the EU is a document adopted in January 2018 – Digital Education Action Plan. The Action plan is the new EU's response to the urgent need to boost digital skills and competences in Europe and to improve the uptake of technologies in education, because (as it is stated in the document) 37% of the EU workforce has low digital skills, or none at all; less than half of children are in schools which are highly equipped digitally; only 20-25% of them are taught by teachers who are confident using technology in the classroom; 18% of primary and secondary schools in the EU were not connected to broadband.

The Digital Education Action Plan includes 11 initiatives to support technology-use and digital competence development in education and has three priorities, setting out measures to help member states meet the challenges and opportunities of the digital age:

- Priority 1: Making better use of digital technology for teaching and learning.
- Priority 2: Developing digital competences and skills.
- Priority 3: Improving education through better data analysis and foresight [3].

Also in January 2018 the EU proposed the renewed vision of the European Reference Framework of Key Competences for Lifelong Learning (2006) in a Proposal for a Council Recommendation on Key Competences for Lifelong Learning (Brussels, 17.1.2018 SWD(2018) 14 final) [4].

The document offers an updated list of eight key competencies – Literacy competence; Languages competence; Mathematical competence and competence in science, technology and engineering and; Digital competence; Personal, social and learning competence; Civic competence; Entrepreneurship competence; Cultural awareness and expression competence.

The concept of digital competence went through serious transformations. As it is underlined in the Proposal understanding and relevance of digital competence has experienced a dramatic boost since 2006 – in the revised version the definition of the digital competence is aligned with the Digital Competence Framework and its associated tools, such as frameworks specifically developed for consumers, educators as well as in line with other existing national frameworks.

Besides, the terminology used for the digital competence definition also was updated (see table 2).

Table 2. Digital competence definition in European Reference Framework of Key Competences for Lifelong Learning (2006) and in Proposal for a Council Recommendation on Key Competences for Lifelong Learning (2017).

European Reference Framework of Key Competences for Lifelong Learning (2006)	**Proposal for a Council Recommendation on Key Competences for Lifelong Learning (2017)**
Digital competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet	Digital competence involves the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, digital content creation (including programming), safety (including digital well-being and competences related to cyber security), and problem solving.

Thus, under digital revolution the world and Europe make every effort to confront the existing challenges and maximize the benefits of ICT. This is evidenced by the scaled strategies for the development of societies and educational systems which actually transform societies and education on a digital basis. It is necessary to note the coherent nature of EU policy in the field of education to the direction of digital transformation – this is about both infrastructure development and the development of digital competence in different groups of the population that is emphasized more and more during the last decades. Another important characteristics of the strategy is that it foresees interaction at all levels and all stakeholders vertically and horizontally: between Brussels and the Member-states, central government, regional and local educational authorities, educational institutions; the education sector and employers; educators, students, parents; formal and informal education.

4 Conclusion

The conducted research has shown a significant progress of Ukraine and the Ukrainian education in the direction of building an information society. Ukraine has worked its way from computerization of the teaching and learning towards informatisation of education. At the same time, the world and the European community move rapidly towards digital transformation of education and learning, making ICT an integral part of modern life, directly linking digital technologies with the knowledge economy.

European belonging of Ukraine, its geographical and mental closeness to the EU, devotion to the European values, contributes to the Europeanization of Ukraine and the Europeanization of the Ukrainian education in particular. The problem of Europeanization is analyzed in the works of many foreign and Ukrainian scholars. In particular, the Ukrainian scholars V. Bashtannik, L. Prokopenko, N. Rudik, O. Rudik, I. Shumlyaev, and others analyse it in terms of terminology, the dynamics of its development within the borders of the EU and beyond, with reference to the research of such foreign scholars as Robert Ladrech, Tanja A. Börzel and Thomas Risse, Johan P. Olsen, Christoph Knill and Dirk Lehmkuhl and others. The issue of Europeanization of education is the subject of study of such foreign scholars as Nafsika Alexiadou, Sotiria Grek and Martin Lawn, Benedicte Robert, Marco La Rosa and others [20, 21, 27].

Researchers define Europeanization as a process of formulating, disseminating and institutionalizing formal and informal rules, procedures, paradigms of politics, styles, modes of action, common beliefs and norms that were first identified and endorsed during decision-making in the EU, and subsequently incorporated into the logic of internal discourses, special features, political structures and policies of the Member States [11].

The issue of Europeanization of education is deeply studied in the works of S. Greck and M. Lown (2012). They characterize this process as a complex one with the following dimensions:

- creation of a new space of activity, thinking, politics through means of networks, associations, structures within the EU borders, strengthening the role of national actors in the design of this space through the interpenetration of political ideas, knowledge, data and practices;
- creation of a common policy or educational space as a result of general regulation by the EU through open method of coordination [10].

Scholars emphasize that Europeanization being a process of EU formation that directly or indirectly relates to this political entity. At the same time, it is a process that transcends the borders of the EU within the framework of globalization and has an impact beyond its borders.

Under the conditions of European integration of Ukraine, the mentioned concept of Europeanization serves as an imperative for the further development of the state policy in the direction of informatisation, transformation of education into a digital-based one along the EU lines. It seems necessary to accelerate the development of the comprehensive strategic framework similar to the EU ones in ICT education area. Not least important is its regular updating (example of the European Reference Framework of Key Competences for Lifelong Learning (2006) and Proposal for a Council Recommendation on Key Competences for Lifelong Learning (2017)) under conditions of rapidly changing reality.

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Information-Communication Technologies of IoT in the "Smart Cities" Projects

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Abstract. In the computing environment of the "smart cities" projects actually a number of complex devices are operating. They are implemented in physical objects connected to the Internet. They, in turn, support a set of diverse communication means and protocols for data exchange. Such system integration ensures efficient supply of a wide range of services, forming due to the combination of both virtual and real physical devices, innovative services formed on the basis of modern information and communication technologies.

The authors analyzed existing in modern "smart cities" projects implementations and architectures developed on the basis of the IoT,, generalized them and defined the principles of their complex application with information technologies of other classes such as cloud computing, Big Data, analytical data processing technologies, as well as their integration with information models of heterogeneous processes and systems presented in the form of databases, stores and data spaces.

The authors designed and implemented the information-technological platform for telemetric accounting of water, heat, gas and electricity consumption focused on the implementation in the "smart cities" projects. Several generations of digital devices for telemetry data transmission with the ability of connection to the Internet network by means of network interfaces (LANs) and mobile network are used in the base version of the offered platform.

The data concerning the implementation in the leading Ukraine technical universities of the specialty "Information Systems and Technologies" majoring in "Internet of Things" with the curricula providing the study of "Internet of things for smart cities" subject are given.

Keywords: Internet of Things, Big Data, smart city.

1 Introduction

The concept of Internet of Things (IoT) was offered by Kevin Ashton in 1999, when the distribution of devices with intelligent sensors integrated with the appropriate communication tools started. Internet of Things are defined as self-organized systems having no conceptual limitations, being the part of the convergent systems and are designed to increase the efficiency of processes in these systems. In its turn the IoT-applications

[1] are defined as sets of connected or integrated objects or devices into the environment. These objects or devices use the standard communication protocols for information exchange. The results of the carried out investigations prove that at present the number of connected Internet of Things, exceed the number of the planet population and their variety and diversity include a lot of devices which can be used as unified block solutions while implementing the innovative projects of the future “smart cities”.

Two areas of the “smart city” concept were clearly defined by the researchers and experts working out the real innovative projects for implementation in modern cities. [2]. On the one hand, it is a methodological view on the technologically concentrated information and communication platform effectively providing the implementation of the key computing algorithms and IT service complexes and systematically integrates numerous diverse devices built into specific city objects and urban environment as a whole. On the other hand it is more socially concentrated concept focusing on the methods, means and ways of formation of the new knowledge-based urban society and innovative high-tech urban economy. A reliable bridge between them are the processes of selection and effective use of data concerning the urban activities, their complex analysis in order to generate powerful tuples of new information services designed to optimize the wide range of the processes of the modern city functioning related by specialist as hypercomplex system. Technology of Internet of Things (IoT) is regarded by many researches and experts as one of the key information technologies focused on effective implementation of such functions.

The term "Internet of Things (IoT)" in early professional publications was defined as Internet Everything, Internet of Everything, Internet of People, Internet of Signs, Internet of Services, Internet of Data, Internet of Processes [3].

In the paper [4], IoT is interpreted as a network of related physical objects. “IoT” integrates people, processes, data and things in order to make the network connections more relevant and valuable than ever before, transforming information into action and creating new areas of application, wider experience and unprecedented economic opportunities for enterprises, individuals and countries in general.

Internet of Things have sets of characteristics formed in accordance with the set tasks in a particular research area. Because of the incomplete formation of the terminology base, it is reasonable to provide the basic definitions and terms characteristic to modern innovation class of information and communication technologies. The basic concept of Internet of Things, technology is the implementation of the paradigm according to which "almost all Internet of Things are interconnected" transformed into the implementation of the following characteristics:

- Convergence provides the ability to process arbitrary types of data (text, photos, video and audio, etc.) by means of any technological device.
- Connectivity - allows you to connect anywhere and anytime.
- Connection - provides the means for communication with any network in any way.
- Content - available from anywhere at any time, without content restrictions.
- Calculations – are available to everyone who has knowledge concerning the principles of operation without limitation of duration and time of access
- Collections - are the set of services or any particular service available for solving an arbitrary list of tasks.

In paper [5], the “Smart cities” application architecture is presented in order to manage the data obtained with IoT devices, and in papers [6], [7] the connection scenarios of IoT devices using Service-Oriented Architecture (SOA) are concidered. Papers [8], [9], [10] provide the frameworks and control system for the analytical processing of BigData of the "Smart city", and paper [11] describes the platform for the provision of administrative services. Information on service-oriented cyber-physical systems for mobile applications of the "Smart city" is given in [12], and for production systems in paper [13]. The multi-level cloud architecture model is described in [14]. In a number of works, the service-oriented approach is actively used in the IoT architecture [15], the integration of IoT devices into traffic monitoring systems [16] and open data from IoT-devices [17], in the systems for monitoring environmental safety, health care and safety (EHS) industries [18], automobiles parking [19].

Creating applications on the IoT platform in the “smart cities” projects it is reasonable to formulate the comprehensive systemic view based on procedures of the unification of relative architecture, innovative information-technological principles and methods of Internet of Things interaction.

2 “Smart city” – Basic Concept

Information and communication technologies are focused on solving problems connected with the growing complexity of urban complexes, urban infrastructure networks, urban population, and stimulate the implementation of the innovative "smart cities" projects of the future. The concept of the "smart city" is intended to be implemented in the complex urban environment including a variety of complex infrastructure systems, the behavior of numerous urban communities, innovative advanced technologies, social and political structures, a diversified economy, etc. The "smart cities" projects provide for the implementation of sound management methods for urban components and subsystems, such as transport, health care, education, power engineering, the system of factors affecting protection and improvement of the environment quality, etc.

Over the past few years, the unprecedented increase in the amount of various types of information flows, which source are social networks [20] and the Internet, that in its turn caused the emergence of the new class of information technologies such as Internet of things technology (IoT) [21], [22]. Information flows from social and sensory networks can be integrated in order to search for hidden correlations and associations to extend the diversity of information and services provided in the "smart cities". Information-technology applications of such type are implemented in a number of innovative projects such as Wiki City [23], City Sense [24], Google Latitude [25]) and in the development of the diverse social and urban sensor networks [26], [27], [28]. The advantages of the integrated use of information resources of social networks and information flows generated by numerous Internet applications are clearly demonstrated in the "smart cities" projects , financially supported by the European Community [29], [30].

The rapid processing of Big Data of poorly structured data in the "smart cities" projects involves a wide range of activities concentrated on the selection, transmission, transformation, storage and analytical processing of information flows concerning the state and processes of environmental pollution, weather, accumulation and utilization of wastes, water supply and other natural resources, heat and energy sources, sensory of city events and incidents. At the same time, mining and transformation of data concerning urban life from social networks are carried out. The technologies of data transmission and selection formed by urban engineering components, are based particularly on the use of wireless sensors integrated into numerical industrial and service information-technological applications. The combination of data obtained from both physical sensors and social sources contributes to the formation of full picture of city-wide processes, complexes, subsystems and structures.

Information systems of the "smart cities" on the basis of modern information and communication technologies provide powerful, intellectual support both to the urban population in general and to municipal authorities, in particular. [31] Figure 1 represents the basic components of the modern innovative concept the "smart city".

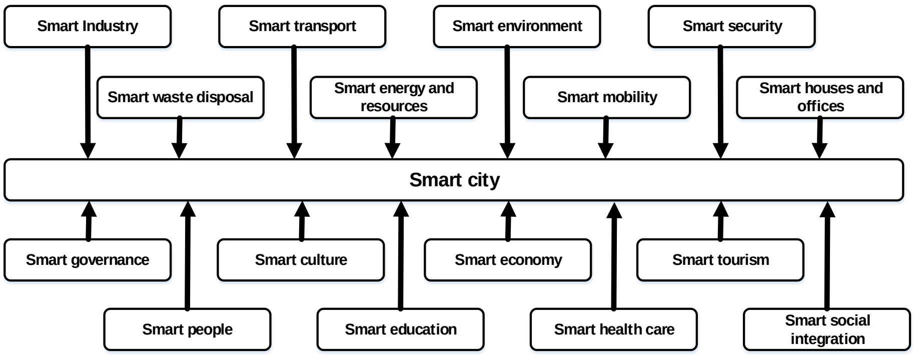

Fig. 1. Components of the "smart city" concept

Analyzing the methodological principles of the development of the integrated information system of the "smart city" of the future the high level of such systems complexity should be taken into account. In general, the modern system of informational-technological support of the main business processes, maintenance of urban engineering infrastructure networks, formation and maintenance of procedures for making optimal decisions at the level of municipal management, efficient formation and functioning of the city socio-communicative environment can be referred to the category of hyper-complex systems. One of the most effective tools for such systems analysis is the structural functional-decomposition approach, the main subject of which is to analyze the basic functions of the separate components of the hyper-complex system, the means and methods providing the performance of these functions and implementing the hyper-complex inter-component interaction of elements of a functionally separated part (subsystem) of the general hyper-complex system. In this case the selection of such functional complexes as the "sensory" subsystem of the "smart city", the network infrastructure of the IoT technologies cluster in the "smart cities", integration of IT technologies with Big Data and Cloud computing technologies, data stores and spaces, as well as Data mining and OLAP are concerned. Only such generalized system approach to the construction of the comprehensive “smart city” information system of the future can generate significant innovative energy effects from its implementation and large-scale implementation with new qualities for its inhabitants living conditions.

3 Sensory Structure of the "Smart City".

At present the primary sensor complexes implemented in specific physical objects or numerous smartphones of the city inhabitants and guests playing the role of socio-communicative mobile sensors, are the informational-technological foundations of IOT technologies cluster in the "smart cities".

Sensors implemented in systems and domain elements of the "smart city" concept are the main sources of generating heterogeneous information sets. Information from sensors is collected due to IoT devices connected to the communication networks. Smartphones connected to mobile networks GSM / 3G / 4G are used for selection and transmission of socially oriented urban data. The data collected in such a way are processed and analyzed in the "smart city" analytical data processing center which virtual prototype is reasonably to deploy on the cloud platform using cloud data stores [32]. The combination and consolidation of data obtained from the sensors in complexes of the domains of different types make it possible to improve significantly the parameters of services and information-technology services provided by the "smart" urban program-algorithmic applications (Fig. 2).

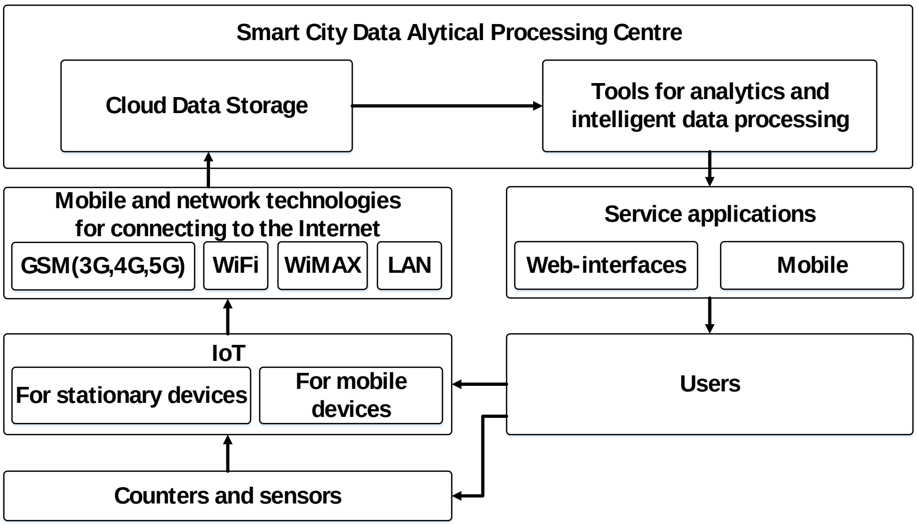

Fig. 2. Virtual "cloud prototype" of the “smart city” analytical data processing centre

The examples of such information-technological applications formed on the basis of functional sensors physically implemented in real objects, as well as socio-oriented sensors such as smartphones, tablets, etc. are:

- "smart illumination" - designed to reduce energy consumption [33] accomplished due to IoT light sensors use [34] along with the comprehensive system for street illuminating adaptation [35].
- "smart noise control" - designed to detect noise sources and identify the points of excessive noise pollution of the urban environment in real time mode [33].

- "smart surveillance cameras" - designed to monitor the security situation in order to track suspicious actions that may endanger the city residents or municipal property [36].
- Modern sensors in the "smart cities" projects are able to generate Big Data. Contextual analysis of data obtained from sensors for identifying hidden correlations plays a key role in the development of "smart" urban information-technological applications [37].

Nowadays the implementation of a large number of projects concerning the development of multi-type monitoring systems particularly for tracking the location of bicycles, cars, and free space in public parking, etc. using sensor complexes and IoT infrastructure is carried out (Fig. 3).

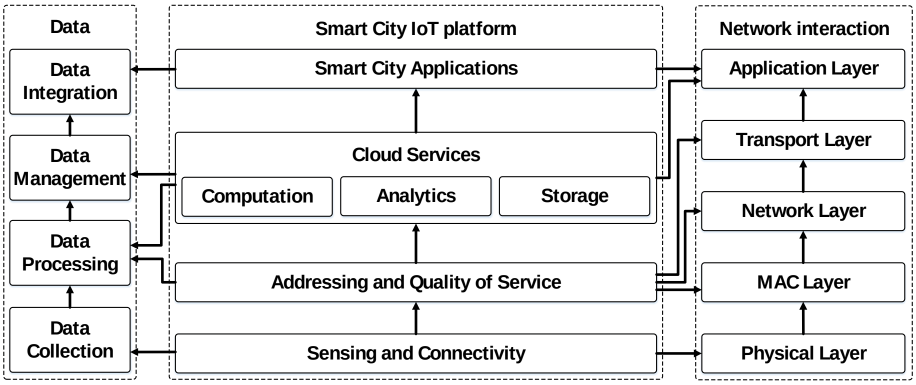

Fig. 3. IoT infrastructure along with the data and communication stacks

Sensor devices and sensors, of RFID and WSN technologies are the main ones in the given architecture at the "sensory and connection" level. RFID technology provides automatic identification of network objects. Wireless Sensor Networks (WSN) are able to collect, process, analyze and distribute data generated in different environments [38]. Due to the availability of compact, cheap, intelligent and widely used sensors (such as built-in video cameras), WSN plays an important role in implementing IoT-based urban applications.

The development of social networks and the widespread use of the smartphones defined the new sensory paradigm. According to it the active participation of citizens in the processes of primary data files formation and their use for management and interaction with the municipal authorities is rapidly growing.

The addressing system provides a unique identification of objects allowing to recognize hundreds of thousands of devices and providing the ability to control them remotely. All devices connected to the network are uniquely identified by their location and have functional able to provide scaled addressing space. It is effective to use IPv6 protocol having the extended addressing space and providing new IoT-devices with unique addresses. The protocol is compatible with state-of-the-art devices and communication technologies, provides versatility, stability, scalability, manageability and ease of use when applied in the devices with limited resources [39].

For the implementation of the "smart city" comprehensive information system of the future wide networks of stationary and mobile sensors, video cameras, street emergency stop buttons and a number of other devices are expanded on the basis of the IoT. The types of sensors used in the “smart city” information systems [40] and by the municipality, the city residents and guests to make optimal decisions based on intelligent analysis of poorly-structured Big Data in real-time mode are shown in Fig.4.

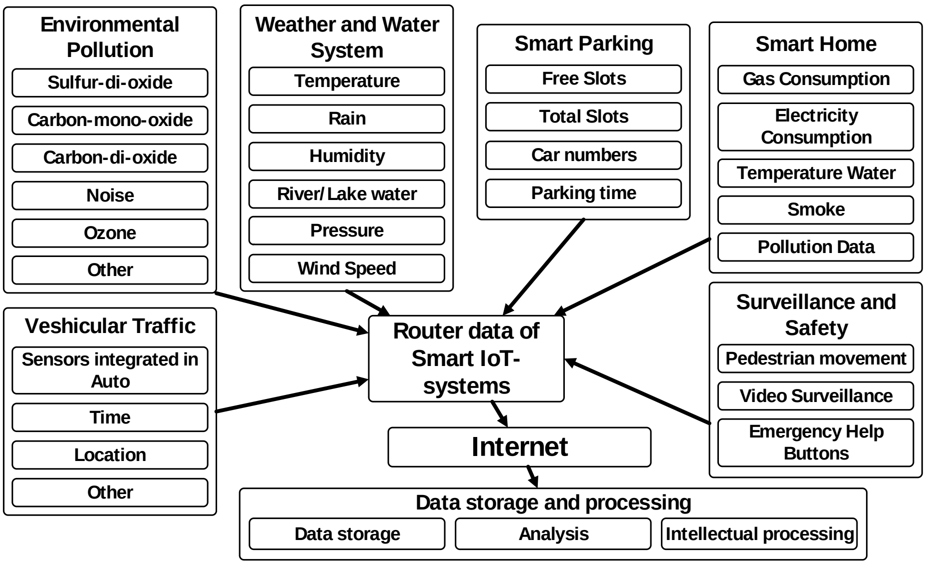

Fig. 4. Sensory structure of the "smart city" using IoT

In "smart houses" as the structural components of the "smart cities", telemetric data from sensors in real-time mode are constantly controlled. Smoke and temperature sensors are used to detect fires, and flowmeters of different types provide monitor processes for electricity, water, gas and heat consumption. "Smart" cars parking places implement the function of intelligent vehicle driving. Meteorological monitoring systems provide data concerning the state of weather, external temperature, precipitation, humidity, atmospheric pressure, wind speed and water level in rivers, lakes and other urban ponds. Usually, rains and melting snow cause floods, so meteorological sensors are used to predict the level of water in reservoirs.

The subsystem of data collection dealing with the state of the environment can generate from the messages about gas pollution, the level of ozone and noise in the city.

4 Generalized Architecture of the "Smart City" Information-Technological Platform

The investigations carried out by the authors made it possible to formulate and specify the basic requirements for the generalized architecture of the "smart city" information-technological platform. The reference architecture model developed according to the indicated requirements provides effective implementation of a wide range of information-technological innovations, such as cloud computing, IoT, BigData, Data Mining, information models of processes and systems in the form of databases, data stores and data spaces in certain realizations. Figure 5 represents the generalized architecture of the “smart city” information-technological platform using the IoT technology cluster roughly decomposed into 6 levels: sensory level, network level, receiving level, storage, processing and visualization level. The sensory level in its turn is relatively divided into three components. The sensors sublevel contains water, gas, electricity and heat consumption meters. It is supposed that both mechanical and smart meters of consumed resources and services can be used in the system. It is predicted that the indicators of mechanical flow meters are recorded by means of impulse converters. The counters are systematic-connected to IoT devices on the basis of the industrial M-BUS protocol, RS485 and RS232 interfaces, analogue and pulse inputs represented in the appropriate sub-level (Interfaces for connecting sensors).

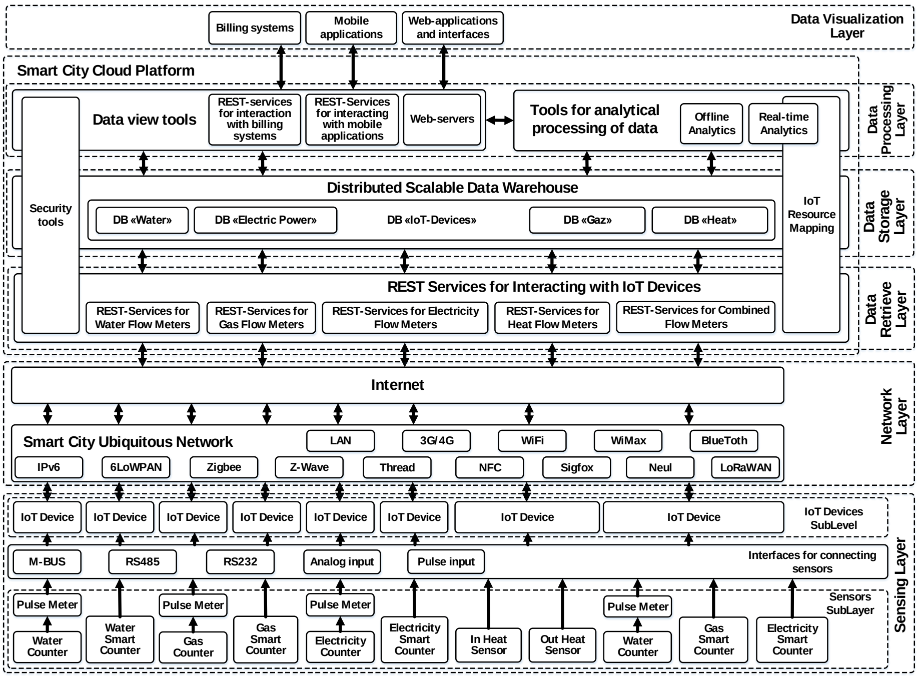

Fig. 5. Generalized architecture of the the "smart city" information-technological platform

At the next sublevel the IoT-devices are provided assuming that different types of IoT-devices with connected meters can be implemented. In order to take into account heat consumption indicators, the use of input and output heat sensors is predicted. In this case, the amount of the consumed heat is calculated as the difference between their indicators.

In a generalized architecture, the network layer contains a widespread urban network of the “Smart city” which by means of LAN, 3G / 4G, WiFi, WiMax or BlueTooth and

IPv6, 6LowPAN, ZigBee, Z-Wave, Thread, NFC, Sigfox, Neul, or LoRaWAN communications technologies provides access of IoT devices to the Internet network.

The next three levels are implemented on the basis of on the "smart city" cloud platform. At the data acquisition level the REST-services for interacting with IoT-devices can be implemented either as specialized (for a certain service, such as water, gas, heat or electricity supply), or combined flow meters. The data sets collected at this level enter the next level and are stored in the distributed scalable data store where the corresponding set of information entities is generated for each IoT-device. Information entities can be grouped into thematic databases. Offline and real-time analytical processing tools and data entries such as REST-services for interaction with billing systems, REST-services for interacting with mobile applications and web servers are grouped on the Data Processing Layer. These tools are used to interact with billing systems, mobile applications, web applications, and interfaces located at the visualization level. Represented in the generalized architecture of the “smart city” information-technology platform Security tools and the IoT Resource Mapping technologies cluster provide security procedures, access rights differentiation and IoT-devices identification.

On the basis of the offered generalized architecture the authors have designed and implemented the information-technological system of telemetric recording of water, heat, gas and electricity consumption focused on the implementation in the "smart cities" projects. Several generations of digital devices for telemetry data transmition with the abilities to be connected to the Internet by means of network interfaces (LAN) and mobile networks were used in the basic version of the offered system. Sensors can be connected to the digital devices using interfaces for connecting sensors.

Newer generations of digital devices can communicate with the REST-service on the remote web server in a dialogue mode. The received data sets concerning consumed services are stored in the distributed scalable database. The next versions of the system predict significant expansion of its functional possibilities using the architecture and data exchange methods typical of IoT-technologies.

5 Educational Course "Internet of Things for Smart Cities"

The citywide information system of integrated monitoring and analysis of payments for consumed resources along with the maintenance of production-business functions can serve as an effective educational-methodological tool in educational processes increasing the urban community "knowledge potential" dealing with the problems of economical consumption and the efficient use of the wide range of resources and services . The processing and analysis of Big Data from sensors, meters and flow meters allows us to develop recommendations for consumers regarding optimal time profiles, operating modes of household equipment and predicted volumes of necessary resources.

At the same time, this system can be used as the training-laboratory stand model for conducting classes with students of a number of specialties, implementation of real course projects and simulation of many processes requiring the study and analysis in the "smart cities" integrated information systems based on information-technological IoT platform.

According to firm CISCO [41] report the IoT market by 2022 will be $ 14.4 billion and will make it possible to:

- improve the customer experience;
- reduce the time needed from the idea of new product creation till its market appearance (time-to-market);
- improve the ways of delivery and logistics;
- increase the employees productivity;
- use the assets effectively while reducing overhead costs.

Training new generation of specialists who are aware in the IoT field is becoming more and more important.

New educational and professional curricula for training specialists in the field of “Information Technologies” are developed in the Universities of Ukraine in cooperation with IT-firms. New methods and approaches to the training of respective Bachelors and Masters at the Universities are changed.

The National University “Lviv Polytechnics” implemented the joint project of the University and the Lviv IT-cluster concerning creation of educational and professional curricula on specializations "Internet of Things", "Artificial Intelligence Systems", "Data Science".

In the Ukrainian Catholic University implemented the innovative Bachelor's curriculum in computer sciences developed in cooperation with the IT-industry representatives.

The specialists training in the educational-professional curriculum on specialty "Information Systems and Technologies" was initiated by a number of leading Ukrainian universities. One of the Master's educational program specialization for specialists training is particularly the ‘Internet of Things”. Within the framework of the above mentioned program, the course "Internet of Things for smart cities" was introduced to the Master's level curriculum. It is based on the knowledge gained in such disciplines as algorithms and data structures; object-oriented programming; database and knowledge; distributed and parallel computing systems; data store; intelligent data analysis for business analytics; web technologies and web design; architecture of computers and networks; information technology for monitoring and data analysis; information systems design.

Introduction of the "Internet of Things (IOT) for the “Smart cities" course into the curriculum makes it possible to use the offered engineering-technical solutions in the process of Masters training in the educational professional program of "Information Systems and Technologies" specialty.

The "Internet of Things for smart cities" course study involves carrying out the cycle of laboratory works, the course project, as well as the development of series of analytical papers.

The topic of the laboratory work is connected with information- technological support of infrastructure engineering networks and life support systems of the city. These are particularly the information systems for recording of gas, water, heat, electricity consumption and other expenses.

The specified laboratory works of the cycle involves the execution of a number of tasks, such as the construction of structural schemes of the relative subsystems, consisting of four levels (measuring level, messages transmission level, data storage level and data presentation level).

At the measuring level the selection and interpretation of the primary measuring converters used to select data concerning the consumption of the relevant resources is predicted. It motivates the student to give arguments about the design decisions he or she made.

At the data transmission level the student analyses the available decisions, selects and explains the choice of the controller, carries out the comparative analysis of cellular network parameters.

At the data storage level the student analyzes the work of data acquisition modules, data loads, selects certain FTP-server, Web server and DBMS.

At the presentation level the student offers solutions concerning the peculiarities of the system web interface.

It should be noted that the topics of these laboratory works can be related to the most diverse aspects of the city functioning.

The students are offered to develop one of the information systems as topics for course project in "Internet of Things (IoT) for smart cities" course:

- monitoring the availability of the city car parking places;
- monitoring the measurements of vibration parameters of city buildings, bridges and historical monuments;
- the city smart illumination;
- analysis of waste pollution levels and optimization of routes for garbage disposal vehicles;
- control of the enterprises and automobile engines CO_2 release;
- monitoring the running water quality;
- monitoring and management of the city energy consumption;
- processes of the water supply network functioning, etc.

The course projects are developed in teams of 3-5 students, and the result of their implementation are mobile information and technological applications.

During semester the students are encouraged to make a report based on the scientific publications in professional journals and collections of scientific papers, scientific-technical reports and reports delivered at scientific and practical conferences. This includes particularly the development of analytical reviews concerning the state and results of scientific research and practical developments on important and perspective research topics. As an example, we give the suggested list of analytical reports:

1. Monitoring systems of leakage and waste release into seas, river basins and ponds in real time mode
2. Systems for monitoring changes in water levels in rivers and ponds on the example of Lviv, Transcarpatia, Ivano-Frankivsk, Odesa, Mykolaiv, Kherson regions
3. Monitoring systems for radiation level measuring in the cities located in the areas of the nuclear power plants influence
4. Monitoring systems for the detection of gas leakage in industrial environments
5. Systems for monitoring the products storage conditions

6. Monitoring systems for toxic levels of gas and oxygen at chemical plants.
7. Detection and monitoring of penetrations into the "Smart House" system
8. Systems for monitoring climatic conditions in museums, libraries, archives.

6 Conclusions

The materials given in this paper were developed by the authors according to the results of investigations carried out during two years in the virtual scientific-research laboratory "The smart city of Ternopil" at Ternopil Ivan Puluj National Technical University.

According to the results of the investigation we can confirm that:

- first, the use of information and communication technologies relating to the innovation technological Internet of things cluster in projects of the "smart cities" of the future is an important scientific task;
- second, the implementation of the "smart cities" information-technological projects should take place in the context of the most comprehensive use of the methodology of the system approach to hyper-complex systems, one of which is the system complex of the modern city;
- third, the information-technological platform for implementing the “smart cities” projects of the future should provide the integrated use of a number of modern technologies such as Cloud computing, Big Data, IoT, Data mining GIS, OLAP, Data Base, Data Weryhaus, Data Space, etc.;
- fourth, certain and almost the most important component of the “smart city” complex information system should be the IoT technologies serving as a methodological basis for the creation of sensory component of the innovation information-technological complex;
- fifth, the "smart cities" information-technological projects should be implemented on the basis of reference architecture model with the previous development of the models and prototypes complex on which industrial technology solutions are worked out;
- sixth, the large-scale design and deployment of the "smart cities" information-technological projects requires creative specialists training in relevant IT specialties and specializations.

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GeoGebra as Means of Improving the Quality of Education

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Abstract. The article substantiates the use of dynamic mathematics software as effective means of formation of the functional thinking of pupils, which directly impact on the quality of mathematical education. The constructive approaches to solving mathematical problems by GeoGebra reduce the weight of analytical calculations. Such approaches put forward the need for skills to constract the desired configuration, take into account the dependencies between its parameters, visualize positions of possible results, even "see" the desired function, for which you need to determine extreme.

The authors use GeoGebra in solving extreme problems using method based on constructing an empirical graph of the relations between the values and defining of extremum. Another method is based on the visualisation of spreadsheets of the values of the empirical function and their analysis.

The effectiveness of the proposed approach was tested during 2015-2017 and was experimentally confirmed in the work on the research topic "The use of information technology in education" through the organization of math group works for pupils in the Sumy region. We tracked the overall level of academic achievement and its dynamics. Since the scale had two positions (right/wrong) and the results of educational achievements were not dependent on each other, we used the sign test. The statistical check at the significance level of 0.05 confirmed the positive impact of the group works on the quality of mathematical preparation of pupils.

Keywords: dynamic mathematics software, GeoGebra, mathematical preparation, quality of mathematical education, constructive approaches, extremum problems

1 Introduction

The realities of modern society determine the technologies that are used in the training of the younger generation. The extension of portable devices (PDAs, smartphones, tablets) and implementation of mobile and blended learning technologies contribute to the strengthening of scientific and methodical searches in the course of the special software, among which dynamic mathematics software (DMS) are allocated in the field of mathematics. Such software is characterized by the ability of dynamically handling of mathematical objects and getting information about their properties. Among this software we allocate The Geometer's SketchPad, GeoGebra, Cabri and similar.

Attraction of such software as means of improving the quality of mathematical education is mentioned in the findings of V. Dubrovskyi, M. Zhaldak, S. Pozniakova, S. Rakov, V. Rakuta, M. Hohenwarter, I. Khrapovytskyi, M. Shabanova, T. Shyrykova and others. We note works [1-5], where the problems of usage of this software at math lessons in secondary schools are considered. The authors offer solution examples of plane geometry, solid geometry, beginnings of the analysis and indicate the implementation of such software for automation of calculations, visualisation of results, investigation of properties of objects etc.

Analysis of these and other works suggests a typical usage of the software when the solution of the problem in the software duplicates the traditional solutions in the notebook, and non-traditional, when the solutions of problems are based on the discovery of mathematical facts through changes of a dynamic structure [5], on the "computer proof" of certain statements at the empirical level through the search of a large number of variants [4], on the construction of correspondences and the use of spreadsheets of values for some parameters for discovery of a certain fact. The last two approaches we have mentioned in the works [6-7] and dwell on them in this article to illustrate the use of DMS as effective means of formation of the functional thinking of the pupils, which directly impacts the quality of mathematical education.

Among the variety of DMS the authors selected software *GeoGebra* as one of the most powerful and free. Each new version of the software is enriched with services and expands its application not only in the field of school mathematics [8].

2 Constructive Approaches to the Solution of Extremum Problems

Geometric extremum problems often cause difficulties even among pupils, whose level of mathematical education is above average. Such problems are supposed to be difficult because of the unusual formulation of the conditions and search for the answer – you need to determine variables, to construct a function which will assosiate these values with unknown one, and then to explore this function on the presence of the extremum. Ordinary pupils don't understand such actions, because they additionally require already established geometric concepts and analytical skills.

Constructive approaches to the solution of such problems with the help of DMS tools, reduce the weight of analytical calculations and highlight the need for skills to constract desired configuration, to take into account relations between parameters, to visualize some positions of possible results, even to "see" the desired function for which you need to determine the extremum.

Example 1. A cone is inscribed in a sphere of radius 4. What should be the height of the cone with the largest volume? [9, p. 202]

The solution of this problem in *GeoGebra* is implemented through contruction of a dynamic configuration and visual observation of the cone volume value, which will be interactively changed by the movement of the base point – the point *F*, which is the center of the cone base (Fig.1).

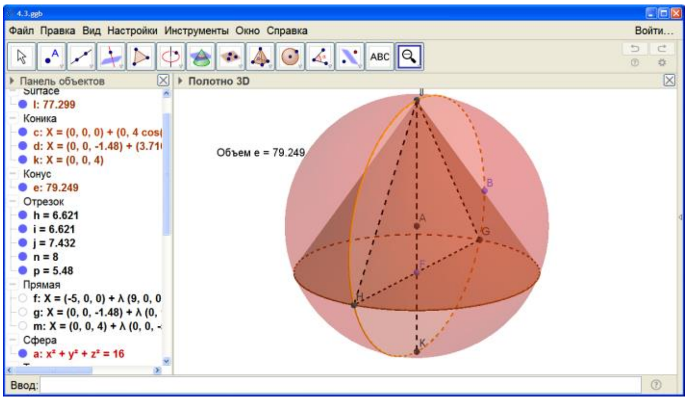

Fig.1. Visual observation of cone volume value

In Table 1 we propose the algorithm for the construction of the configuration of this problem by *GeoGebra*.

Table 1. Algorithm for the construction of geometric combination of the bodies

Constructive actions of a pupil		Computer tool
1	To construct a sphere of radius 4.	*Sphere with Center and Radius*
2	To construct an arbitrary line passing through the centre of the sphere – the point *A*.	*Line*
3	To construct the plane α that is perpendicular to the given line and passes through the centre of the sphere.	*Perpendicular Plane*
4	To construct the curve of intersection of the given plane and the sphere – the big circle of the sphere.	*Intersect Two Surfaces*
5	To construct an arbitrary point *U* on the circle and the line *UA*, which passes through it and the centre of the sphere– the axis of the cone.	*Point, Line*
6	To construct another point of intersection of this line and the circle – the point *K*.	*Intersect*
7	To construct the segment *UK* which connects these two points of intersection.	*Segment*
8	To construct an arbitrary point *F* on the segment *UK*.	*Point*
9	To construct in the plane α the line, which is perpendicular to the cone axis and passes through the point F.	*Perpendicular Line*
10	To construct the point of intersection of this line and the big	*Intersect*

	Constructive actions of a pupil	Computer tool
	circle of the sphere – the points H and G.	
11	To construct the triangle UHG. It is inscribed in the big circle of the sphere and is the axial cross-section of the cone inscribed in the sphere.	*Segment*
12	To construct the circle which passes through the point H. The axis of the cone is its axis. Built circle is the base of the cone.	*Circle with Axis through Point*
13	To build the cone.	*Extrude to Pyramid or Cone*
14	To calculate the height and the volume of the cone.	*Distance or Length, Volume*

Let consider other methods of solving this problem.

1. Method is based on the construction of the empirical graph of the relation of the cone height and its volume by the *Trace* tool.

The use of the *Trace* tool expectes the construction of a curve, points of which have the particular property. If you use this tool, than during dynamic changes of the initial construction the selected point will leave a trace, which will be the locus with the desired property.

If you do steps 1-14 (Table 1), than additionally constructed point *L* may leave such a trace. Its abscissa is equal to the value of the height of the cone, and its ordinate is equal to the value of the cone volume. In the parametres of point *L* you need to order the service *Trace On*. The point *F* moves with the movement of the point A. The built trace of the point *L* is the empirical graph of the function of the cone volume value that we are interested in (Fig.2).

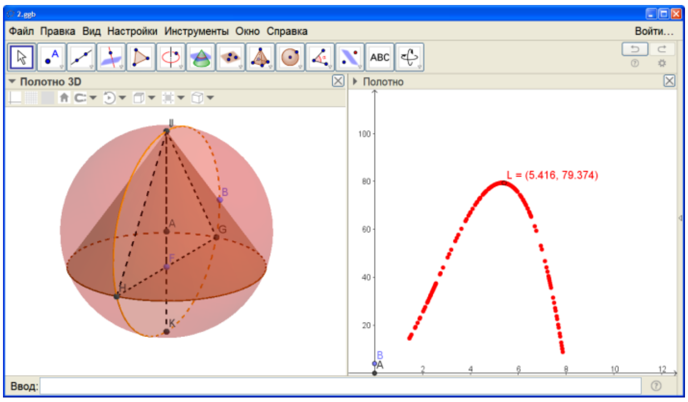

Fig.2 Construction of the empirical graph of the function of the cone volume value by the *Trace* tool

The extremum of this function is obvious. There is no doubt that the maximum for the cones volumes exists and it is unique.

Note that you can also use the *Locus* tool, which will automatically build the empirical function of volume value (Fig. 3). The result of this tool is similar to the result of the *Trace* tool, and the difference is in the output format of the result: after the *Locus* tool the graph is continuous curve, and after the *Trace* tool the graph is bitmap.

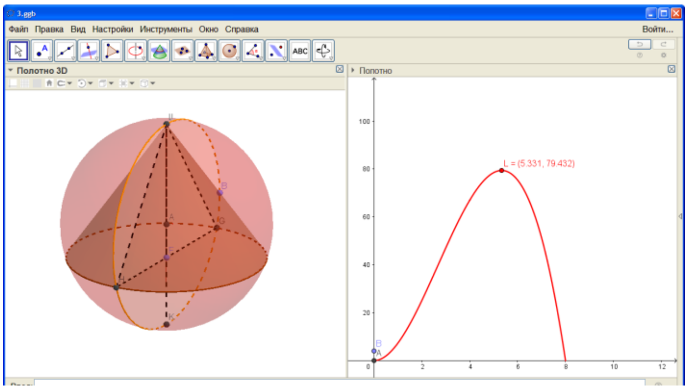

Fig.3 Construction of the empirical graph of the function of the cone volume value by the *Locus* tool

2. Method is based on the displaying of the spreadsheet of values of the empirical functions and their analysis (Fig. 4).

After constructing the main configuration the spreadsheet, that displays the values of the height of the cone and the cone volume, is created. During the change of the position of the base point this spreadsheet is filled with the appropriate value sets. The analysis of these values allows identifying the functional relation between the cone height and the cone volume, to see extreme volume value and make a conclusion about the corresponding value of the cone height.

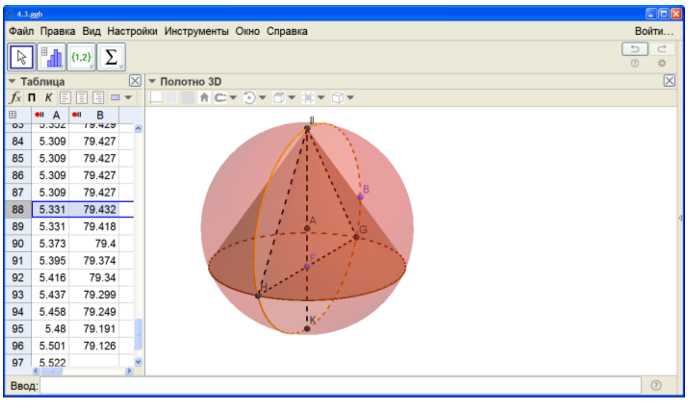

Fig.4 The spreadsheet with values of the empirical function of the cone volume

For the application of the described method pupils are acquired to master the tools and the awareness of a configuration to search for answer: to see the relation between the input and the result without the use of derivative, to know only the definition of the cone and its volume.

The algorithms for solving the problem based on the described methods are shown in Table 2.

Table 2. The algorithm for solving the extremum problems based on the constructive method

Method	Description of possible solving algorithm
Using the *Trace* tool (Fig. 2)	1-14. The steps are similar to the previous method of solution. 15. To construct the point *L* with the following coordinates: the x coordinate is the value of the cone height, the y coordinate is the value of the cone volume. 16. To order the service *Trace On* in the point properties. 17. To define the maximum 79,374 of the empirical function with the help of the trajectory of the point *L*.
Using the *Locus* tool (Fig. 3)	1-15. The steps are similar to the previous method of solution. 16. To construct locus using the *Locus* tool, choosing the point *L* as a point creating locus and the point *F* as a driver point. 17. To determine the maximum 79,374 for the continuous graph of the locus (of the point L).
Using the Spread-sheet of values (Fig.4)	1-14. The steps are similar to the previous method of solution. 15. To add *Spreadsheet View*. To order the service *Tracing to Spreadsheet* for values of the cone height (in Fig.4 it is the value *p*) and the cone volume using the context menu. 16. To observe appearance of the numerical value of the cone height and the cone volume value changing the position of the base point F. 17. To analyze the dynamics of changes in the volume value – value is growing to a certain point, and then falling. Critical value 79,432 is achieved when the height of the cone is equal to 5,331.

The analytical method for solving this problem requires to write the formula of the cone volume function and differentiate it further. According to the task:

$$V = \frac{1}{3}\pi(8h^2 - h^3),\ V' = \frac{1}{3}\pi(16h - 3h^2) = 0,\ h = \frac{16}{3} \approx 5{,}33,\ V_{max} \approx 79{,}43.$$

The results of the analytical solution coincide with the results obtained by the constructive method (Fig.5).

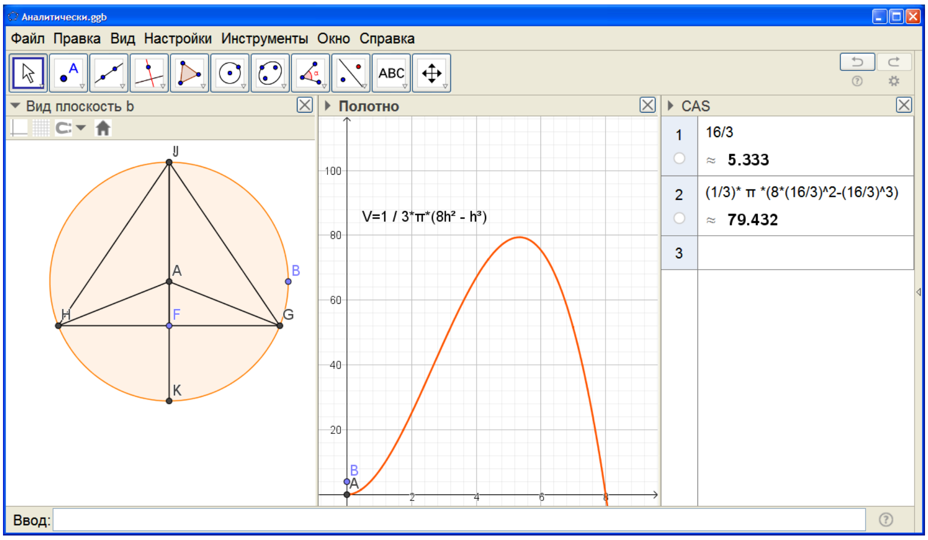

Fig.5 Graph of the cone volume function built analitically

Remark.

1. The empirical function of volume built by the *Locus* tool is not perceived by the software as an independent object, so using the *Extremum* tool or the *Function Inspector* tool to determine the maximum quickly is impossible. Extreme values of built function need to be determined visually.

2. Numerical results can often be "unattractive" or approximate, as are calculated in numeric format with early prescribed accuracy. This causes additional need either in formulaic expressions of desired function and analytical finding of its extreme values or at least in the check of coincidence of graphs of the empirical function and one that is found analytically.

Example 2. The sum of the lengths of the cone base radius and its height is constant and equal to 10. At what ratio of the radius and the height volume of the cone will be the biggest?

Let’s describe the possible solution algorithms.

Method 1 (traditional, Fig.6).

1. To construct points *O(0,0), A (10,0)* and the segment *OA*.

2. To construct the point *B* on the segment *OA* (segment *OB* determines the cone base radius).

3. To construct the point *D(0,BA)* (the segment *OD* determines the cone height) and add *3D Graphics View*. As *Graphics View* and *3D Graphics View* are interactively linked, then the points *O, A, B, D* will appear on *3D Graphics View*.

4. To construct the circle with the centre in the point *O* and the point *A* on the circle – the base of the cone.

2. To construct the cone with the height *OD* using the *Extrude to Pyramid or Cone* tool.

3. To calculate the volume of the cone using the *Volume* tool.

4. To calculate (via the *Input Field*) the ratio of the lengths of the cone base radius and the height of the cone – number *h*.

Changing the position of the point *B* we are observing the value of the cone volume. The biggest value of the cone volume 155,1 is achieved when the ratio of radius and height is equal to 2.

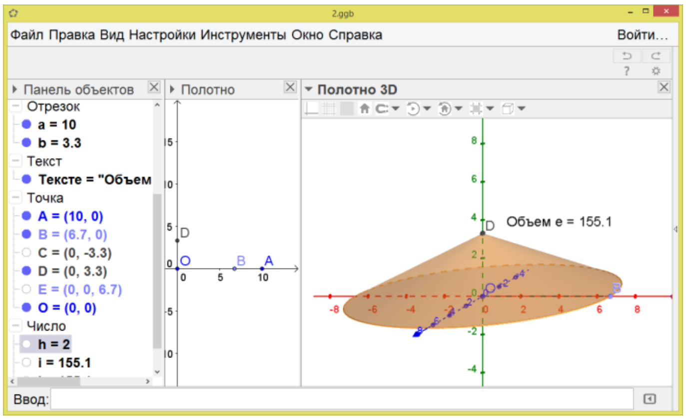

Fig.6 Visual observation of the cone volume value.

Method 2 (using the *Trace* tool).

1. To construct a slider for the parameter *a* in the range [0,10].

2. To construct points *O(0,0)* and *A(a,0)* (the segment *OA* determines the cone base radius).

3. To construct the point *B(0,10-a)* (the segment *OB* determines the cone height).

4. To construct the cone and calculate its volume as in the previous method of solution by adding the *3D Graphics View*.

5. To construct the point *C(a/(10-a),volume b)* and order the service *Trace On*.

6. To determine the maximum 155,1 of empirical function using the trajectory of the point *C*. It is achieved if the cone base radius is twice its height.

Method 3 (using the *Locus* tool, Fig.7).

1-4. Steps are similar to Method 2.

5. To construct the point *C(a/(10-a),volumeb)* and the locus, using the *Locus* tool choosing the parameter *a* as a "driver" point and the point *C* as a point creating locus.

6. To determine the maximum 155,1 of the empirical function using the continuous graph of the locus (of the point *C*). It is reached at the ratio which is equal to 2.

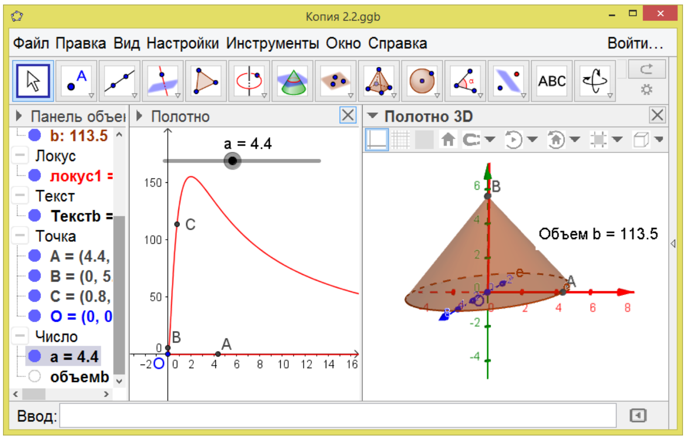

Рис.7 The empirical graph of the function of cone volume built by the *Locus* tool.

Method 4 (using the spreadsheet of values of the empirical functions, Fig.8)

1-4. Steps are similar to Method 2.

5. To construct the point *C(a/(10-a),volumeb).*

6. To add the Spreadsheet and order *Tracing to Spreadsheet* for values of the ratio of the length of the cone base radius to its height (value *f*) and volume.

7 To observe the appearance of numeric values, relations and volume value changing the position of the base point *A*.

8. To analyze the dynamics of changes in the volume value – value is growing up to the certain point, and then falling. Critical value 155,1 is achieved at the ratio of 2.

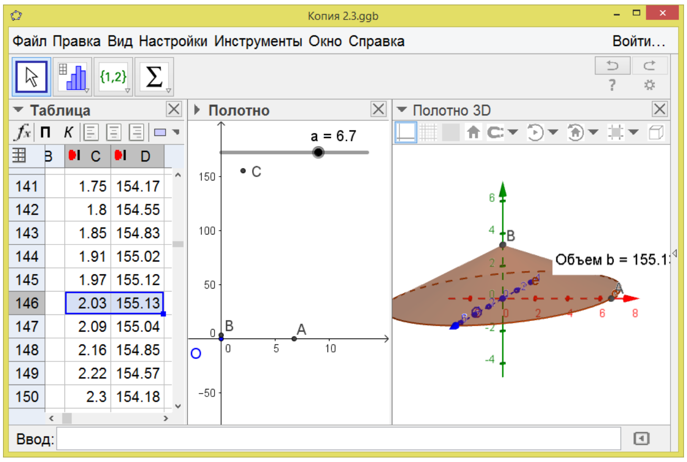

Fig.8 The spreadsheet with values of the empirical function of the cone volume value

An analytical method of solving the problem by writing the cone volume function and its differentiation gives the following results:

$$V = \frac{1}{3}\pi(10r^2 - r^3), V^{/} = \frac{1}{3}\pi(20r - r^2), r = \frac{20}{3}, h = \frac{10}{3}, \frac{r}{h} = 2, V \approx 155{,}1$$

The construction of the graph of this function shows an absolute coincidence with the empirical graph (Fig. 9).

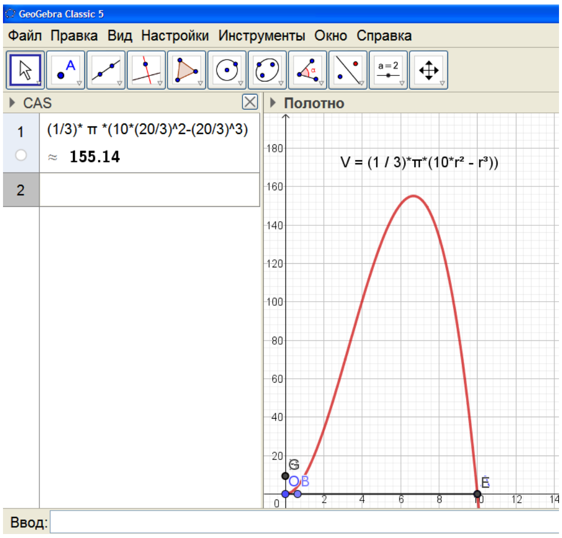

Fig.9 Graph of the cone volume function built analitically

Remark. By analyzing the spreadsheet it becomes evident that the value of the volume and the value of the ratio of radius and height are given with a certain approximation (it is additionally possible to demonstrate changing the format of output values: one digit after the decimal point, two, etc.). So you need to find the results in additional searches of more accurate solution by analytical methods for the confirmation of the empirical fact.

It is very difficult for students to aware an analytic formula of the volume function. The students are not always able to express the relation between the values correctly according to the condition of the task, to determine which variable is independent, and which one is dependent. Mistakes are often in finding the derivative of the function. Such problems are fixed by the subsequent construction of the graph of the analytical function and the coinsidness of the last one with the empirical graph.

In General, the solution of geometric extremum problems with the help of described methods is subordinated to the following algorithm of actions (Table 3). This algorithm contributes to the development of functional thinking of pupils due to the possibility of dynamic representation and processing of a variety of graphical, numerical or algebraic data: we can measure parameters of geometric figures, verify on the basis of these measurements quantitative ratios (between the lengths, areas, angles, etc.), dynamically changing the shape of the original object. Functional relations can be obtained in the form of a spreadsheet of values or graphically.

Table 3. Algorithm for solving the extremum problems based on the constructive method

№	Action description	Remark
1	Constructing geometric figures or its part using the given parameters	A figure should be built in such a way that the analyzed value depends on only one variable, the other parameters must be fixed
2	Output of functional dependencies (graph or spreadsheet of empirical functions values)	As the dependence is described by one variable, the independent point must provide dynamic changing of only one parameter. As geometrical quantities are nonnegative, then for constructing the empirical functions we can use the first quadrant
3	Interpretation of the empirical dependence	Dependence will be empirical, because the analytical expression of the function is unknown
4	Analytical confirmation (without a computer)	The output of the dependence formula in a notebook or on the board remains an obligatory element of the solution and requires the ability to operate the relevant mathematical apparatus
5	Verification of the matching between analytical and empirical dependences	The verification has more applied and formal character ("analytic" graph should coincide with "empirical")
6	Analysis of the answer (if there are critical points, how many of them are exist, what are the conditions of their existence or absence, etc.)	

3 Improving the Quality of Mathematical Education During Math Group Works

Below we will describe the peculiarities of organization and conducting of pedagogical experiment involving the use of dynamic mathematics software as means of improving the quality of mathematical education.

The effectiveness of the described approach was approved (2015-2017) and experimentally confirmed by the results of pedagogical research within the research topic "Use of information technologies in education", which was performed by faculty of the Departments of Informatics and Mathematics of Makarenko Sumy State Pedagogical University in the experimental classes of secondary schools of the Sumy region.

Described approaches to the solution of mathematical problems were implemented in the frame of math group works for pupils. Members of the group works had the opportunity to attend classes once a week. The class work was conducted one hour and provided solution of several problems of varying complexity from separate topics of school mathematics course. Also it was expected to solve similar problems at home.

Below there are the examples of problem conditions with the research content, which were offered to pupils on group works "The extremum of the function" (task level is different, so you should previously check the level of educational achievements of those to whom they will be offered).

1. Taking a segment of length 20 as a flexible wire, constract a rectangle from it. Changing the lengths of the sides, study its area. When will it be the biggest?

2. Construct rectangles: a) with different area and different perimeter; b) with different area but the same perimeter; c) with different perimeter but the same area; d) with the same perimeter and the same area.

Methodological comment. Problems are simple at first glance, but experience of their solutions with pupils shows that tasks a) and b) are solved faster than tasks c) and d). Common mistake is constructing of a rectangle that is a rectangle only visually, and it is transformed into a quadrilateral by changing the position of one of the vertices. We advise pupils firstly to construct a rectangle (!), then a rectangle in which the perimeter is fixed (for example, 20 as in problem 1). It requires from pupils to know the basic constructions of figures using compasses and ruler, which were studied in the 7th class. After that it is better to change the value of perimeter and see, whether the constructed figure remains a rectangle. If actions are correct, then you can study the area value with a fixed perimeter (using the *Trace* tool, the *Locus* tool or the spreadsheet).

3. There is a rectangle No. 1, the form of which can be changed by movement of the point *A* (the lower right vertex moves along *Ox)*. The perimeter of the rectangle is always equal to 20. Construct the dependence graph between its length and width.

4. There is a rectangle No. 2, the form of which can be changed by movement of the point *A* (the lower right vertex moves along *Ox*). The area of the rectangle is always equal to 15. Construct the dependence graph between the length and width of rectangles with equal areas.

The answer is: the hyperbola x*y=15 (constructed, for example, as a trace of the upper right vertex).

5. The rectangle No. 1 retains its perimeter, and the rectangle No. 2 retains its area. Find the rectangle that has these perimeter and area simultaneously. Does the problem always have a solution?

Answer: the intersection points of the traces constructed in problems 3 and 4 define the upper right vertices of the desired rectangles.

The following problems were proposed for independent research and solutions.

6. Study the area value of a net of paper packaging (in the form of a parallelepiped), which has constant volume of 200 cm^3. Is it possible to save material?

7a. Study whether the area of an isosceles triangle, in which only the length of the leg is known, has a maximum.

7b. Study whether the volume of a cone, in which only the length of the generatrix is known, has a maximum.

8a. Among inscribed in an isosceles triangle rectangles one has a maximum perimeter and the other has a maximum area. Do these extremums preserve when you change the base of the triangle?

8b. Among the inscribed cylinders one has a maximum volume and the other has a maximum area. Do these extremums preserve when you change shapes of the cone?

At the beginning and at the end of the group works pupils were asked to give answers to the test questions, which were compiled based on questions of External independent testing (the first and the second part of the test of 2008-2010, which, we believe, were more difficult than recent years tests) and which were positively evaluated by experts in the field of learning math as a test which can verify the level of mathematical preparation of a high school pupil.

The maximum number of test scores is 25.

We tracked the general level of educational achievements and its dynamics. As the nominal scale had two positions – right/wrong, the results of each member of the sample were dependent, but the results among members in the sample were mutually independent, we have applied the sign test for the processing the general results.

The experiment involved 72 people.

The null hypothesis is that the group works does not impact on the quality of mathematical preparation of pupils. The alternative hypothesis is that the quality of mathematical preparation is changed.

At a significance level of 0.05 critical statistics value $G_{crit}=28$.

The Table 5 shows the results of the tests (green – the result increased, yellow – the result does not change, red – the result decreased).

Table 5. The test results

№ resp.	change type	№ resp.	change type	№ resp.	change type
1	+5	25	0	49	-2
2	+3	26	+2	50	-2
3	+2	27	+4	51	-1
4	+6	28	-1	52	+6
5	-4	29	-3	53	+2
6	-1	30	0	54	+5
7	0	31	-2	55	+6
8	-2	32	0	56	+3
9	-1	33	-1	57	-2
10	+6	34	+2	58	-3
11	+2	35	+3	59	-1
12	+3	36	+2	60	-1
13	-1	37	0	61	0
14	-2	38	+4	62	0

15	-4	39	+2	63	+2
16	-2	40	+3	64	-2
17	+3	41	+1	65	0
18	+3	42	+1	66	-3
19	0	43	+1	67	-1
20	+2	44	-1	68	+2
21	0	45	-2	69	+2
22	+3	46	+2	70	-1
23	+3	47	+2	71	-1
24	0	48	+2	72	+2

According to the rules of decision making we have that G_{empir}=26. As the empirical value is less than critical, the alternative hypothesis about the impact of the group works on the quality of mathematical preparation of pupils is accepted, and such impact is positive, as the number of positive shifts (35 respondents have increased their rates) exceeds the number of negative ones (26 respondents showed a decrease in the general test result).

4 Conclusion

1. The purpose of mathematics education is not only learning of the concept of function, but the readiness to analyze the obtained values and their relations. So the tools that accelerate, simplify and visualize the calculations, construction and provide the ability to dynamically vary the variables for awareness essential relations between them, should be involved in the training process. Such tools in the teaching of mathematics are dynamic mathematics software. Their usage allows not only to organize the heuristic search, but also to free up time for additional independent studies to demonstrate the output of mathematics to the practical level of children's experiences and the need for its study.

Note that the involvement of DMS to solving mathematical problems does not provide the knowledge of math formulas, concepts, or functional dependencies, but it is a tool that contributes to developing pupils' research abilities, mathematical thinking and critical view on any statement.

2. Nowadays math teacher needs to demonstrate all the possible ways of solving math problems. It concerns not only analytical or geometric approaches, but also the use of specialized software. The wider the list of ways of finding the answer, the greater the probability of a correct solution of the problem is (at least through the possibility of answer verification).

3. As our experience shows, the involvement of DMS to the solution of problems not only demostrates an additional way of using information devices (tablets, smartphones, computers, etc.) to an average pupil, but also forms and helps to im-

prove the quality of mathematical preparation, which is confirmed experimentally on a significance level of 0.05 on the sign test.

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Adaptive Technology for Students' Knowledge Assessment as a Prerequisite for Effective Education Process Management

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Abstract. Despite the rapid development of intellectual systems and their implementation in education process, the knowledge assessment technologies are almost the same as decades ago. This paper presents an intellectual system approach to the student's knowledge evaluation process, based on adaptive mechanisms development. It is an individual directed systems and it allows one to correct the questions complexity levels in real time, depending on the average students score and to reduce the examiner's influence to the evaluation process. Besides, the proposed system allows one to consider not only the testing result itself, but also different criteria, like time, used by a student to answer the question. According to this is idea, the assessment can demonstrate not only student's pure knowledge, but also his skills and ability to use obtained knowledge in different situations. The experimental results that show the system's effectiveness are presented.

Keywords: Intellectual Systems, Distance Education, Knowledge Evaluation.

1 Introduction

Over the past decades, intellectual systems usage and process automation in general can be found in the most diverse areas of human activity, and the education sector is no exception. Intellectual systems are used as a tool for creating mew courses, to plan students and teachers effective work, to evaluate various electronic sources and information resources, and to automate the assessment of students' knowledge [1, 2].

Standardisation of the student assessment results has become especially relevant within the Bologna Process, designed to create and spread the common education standards in different countries. But, at the same time, such systems use the testing as a way of primary evaluation of the trainee's knowledge, which does not always allow to evaluate his skills fully.

Comprehensive knowledge assessment is very important lately, because, due to the rapid science development and the widespread use of computer and information technology, the number of requirements for a specialist is steadily increasing. These requirements are far from being concrete and unambiguous, and the assessment of such specialists is made, taking into account various skill scores. For example, during the interviews in IT companies, students are often asked questions that do not require a specific answer, but which can show the way, the applicant thinks, like, "how many tennis balls fit into a school bus." Obviously, it is impossible to evaluate the answer for such a question using the classical testing system, but it is not possible to conduct a detailed conversation with each student during the exam.

Furthermore, distance education and self-education are gaining in popularity very fast and perfectly complement the classical education system in schools and universities, making it possible to acquire necessary knowledge, for example, for working people with the lack of free time, or residents of other countries. Assessing these student's knowledge is another problem, since the teacher's participation is minimized, or he is not present at all, and the trainee's skills can be assessed only according with his specific answers. It is also necessary to take into account the numerous courses conducted by large companies for their own employees [3]. It is much more profitable for a company to retrain a qualified specialist, than to search for a new one, spending money and wasting time, not to mention the risk associated with attracting a new employee with uncertain skills level.

Considering the speed of technological development, when a certain standard or methodology can be developed and become obsolete within several decades, or even years, it's impossible to verify the evaluation system correctness on a large number of students, the system should immediately react to the current student's level, their knowledge and external requirements [4].

Thus, there is a need to develop an intellectual system, that would be able to consider not only the correctness of a given by a student answer, but also take into account different criteria of his answer [5]. Moreover, very important is the ability of such system to adapt itself, adjust the complexity of the questions in order to give the most objective assessment not only to the student's knowledge as such, but also the ability to apply this knowledge in practice and to use it in various situations.

The article presents the basis of such system, shows its ability to change the questions complexity and to take into account various criteria, for example, the time, used by the student for answering each question.

2 The Method for Adaptive Correction of Questions Complexity Scale

The necessity to objectively evaluate the complexity of the questions, used to assess students' knowledge, is obvious while creating the new education course, that can be unknown not only for students, but also for tutors [6]. According to the classical methodology, the complexity scale is set by an expert or examiner, that always has an element of subjectivity and requires a thoroughly revision using statistical data after repeated use of such a complexity scale [7]. However, considering the modern world realities, the results must be obtained very quickly, and the price of the mistake during the evaluation can be too high [8]. Not to mention the impossibility to collect a sufficient amount of statistical data, considering a large number of narrowly focused courses, primarily adapted to individual specialists training who must be ready to start their work immediately after graduation.

Adequate consideration of the questions complexity is also important during the study of classical fundamentals, for example, mathematics or physics. It is impossible to verify the student's knowledge for the entire course, it would take almost more time than learning itself, so the questions selection during assessment should be optimal.

Solving these problems is the main goal of creating an adaptive knowledge evaluation system. Being inherently individually directed, it will allow to assess the knowledge of each student more accurate, while being free of the flaws such as subjectivity or predisposition. For example, it makes no sense to ask simple questions the student who gives excellent answers, and on the contrary – it is illogical to give complex tasks to the student who has shown his abilities to be below average. But first the proper scale of questions complexity, based on the students knowledge and their abilities, must be created.

The adaptive complexity correction system is based on the following simple principle – if the student gave the wrong answer to the question, this question should be considered to be more complicated, and the right answer reduces the question complexity. Of course, while implementing this system, many nuances must be taken into account, for example, the overall score or other indicator of the student's progress and knowledge, the statistics of answers to a particular question, and others.

Let the set $Q = \{q_i\}, i = \overline{1,m}$ be the set of questions, used for trainee's knowledge evaluation, m the overall number of questions in the set. Then $p(q_i) \in (0,1]$ is the complexity of each question.

According to the classic methods, that don't use intellectual or any other knowledge evaluation systems, the complexity of each question is determined by the tutor or examiner. Let the $p_i^0, i = \overline{1,m}$ be the predetermined questions complexity, according to which the tasks assignment and, later, the estimation is made. According to the adaptive assessment system main idea, this value is not a constant, but depends on students' answers in real time.

At the same time, the system should not contradict the following principles:

1. The correct answer to the question reduces its complexity, and on the contrary – if the answer is incorrect, the question is considered to be more difficult.
2. The corrected question complexity can not go beyond the previously established scopes, that is, it must always belong to the interval $(0,1]$.
3. The more students pass the test, the less influence each individual answer has on the question complexity.
4. 4. The question complexity should be adjusted depending on the total score of the student giving the answer. If a student, that has a comparatively high total score, gives the incorrect answer, the question complexity should increase by a bigger value than if the incorrect answer is given by the trainee with lower total score. And on the contrary – the correct answer of the student with a lower overall score

reduces the complexity of the question by a bigger value than the correct answer of the student with a high overall score.

According to these principles, after passing the test by each trainee, the complexity of each question should be recalculated according to the following formula:

$$p_i^j = p_i^{j-1} + f_i(p_i^0, m, d^{j-1}, Z), i = \overline{1,m}, j = \overline{1,n},$$

where n – the overall number of trainees, who pass the test, m – number of questions used to assess knowledge, p_i^j – the corrected question complexity, p_i^{j-1} – the question complexity, used during the previous trainee's testing, f_i – the function, used to correct each question complexity, according to the mentioned principles: p_i^0 – the predetermined questions complexity, amount of students m, d^{j-1} – the overall score of previous, $(j-1)$ -th trainee, who answered the question, Z – coefficient, that depends on the deviation of the given answer from the correct one.

According to the formula above, the questions complexity is recalculated in real time, after passing the test by each student that provides the ability of the system to work effectively without having a large amount of statistical data.

By assuming the presence of a large number of trainees, a conclusion can be made, that the value of the complexity level converges to a constant value.

At the same time, such adaptive system assumes the availability of initial data that are set by the examiner or expert, in particular, a preliminary complexity scale p_i^0. The situation when the initial questions complexity is not known must be considered. For example, when starting a new course, or if the examiner strives to objectify the assessing knowledge process. In this case, the students overall scores distribution, based on their previous education successes, or one of the additional heuristics can be used, and depending on this, the initial questions complexity can be distributed.

Obviously, students who passed the test first, can get a significant bias evaluation due to randomness factors. Thus it makes sense to recalculate their scores, using the previously acquired information about their correct answers, and applying a new questions complexity scale, obtained after passing the test by a certain number of students.

3 Multi-Criteria Knowledge Assessment System

Considering the modern world realities and the information society features in particular, specialists in many branches, especially those related to computer and computing technology, interacting with other people and working on large projects, are more often facing problems that require an integrated approach and the ability to apply skills from various branches of science. The knowledge availability is no less valued than the ability to apply them in practice in various situations. The requirements for such specialists can not always be clearly formalized [9], therefore, it is impossible or very difficult to assess their knowledge and level of their preparation by using the classical systems.

In practice, companies and employers solve the problem of adequate assessment by means of numerous interviews, during which not only the student's dry knowledge is analyzed, as it is done in universities, but also his capacity for logical thinking in general, the ability to find a non-obvious way out of complex problems and his ability to analyze some steps forward. It is obvious that it is often impossible to use such methods in universities or for any other education process, due of the limited amount time and resources, and the large number of trainees. Similarly, the use of widespread testing will can not guarantee the desired results.

Solving this problem is possible, using the integrated or multi-criteria knowledge assessment system. It is based on the following principle – to assess the student's knowledge not only for each specific answer to the question, but also to consider his answers in general, and at the same time, to evaluate each answer from several points of view. For example, a student who failed to give a correct final answer to the assigned task, but who demonstrated the correct solving algorithm, will get a greater score than the one who gave the correct intermediate answer, but was guided by this erroneous opinion.

One of such criteria, in addition to the answer itself, can be the time used by the trainee to find the answer. In many situations, time is the decisive factor, and an incorrect or untimely decision can have serious consequences like material damage, financial losses, or even environmental or technological disasters. First of all, it applies to workers of rescue structures, power stations and other strategically important facilities. But, recently, the speed of decision-making is important for many office workers dealing with computing technique [10]. The best example of this is the attack of the virus “Petya”, when some large companies managed to repel a virus attack due to, first of all, the attention of one or two employees who noticed an abnormally rapid files distribution from a single source and blocked this source, which ultimately saved the company from huge financial losses. And, although the simulation of such a situation during the testing is quite difficult and expensive, it is quite possible to assess the speed of decision making or answering the question.

Designing such a system, the following factors should be considered:

- The answer to the question received from the trainee is correct, incorrect or partially correct;
- The answer was given within the prescribed time interval, with an excess, or it was not given at all;
- Answers received after the time expiration are considered to be incorrect, or taken with the application of appropriate penalties.

Considering the simplest version of the assessment system, taking into account the time spent on the answer, the following formula holds:

$$r = \frac{\sum_{k=1}^{m} p_k \cdot \chi(k) \cdot \delta(t^k \le T^k)}{\sum_{k=1}^{m} p_k},$$

where r – the overall testing result, the test consists of m questions, p_k – the complexity of k-th question, $k = \overline{1,m}$, $\chi(k)$ and $\delta(t^k)$ – coefficients, that depend on the answer correctness and time, used by trainee to give it, $T^k, i = \overline{1,m}$ – the maximal time, determined by the examiner to answer each question.

To simplify the model, assume that $\chi(k)$ can take only 2 values – either the answer is correct or incorrect:

$$\chi(k) = \begin{cases} 1, & \text{if the answer for the } k\text{-question is correct;} \\ 0, & \text{otherwise.} \end{cases}$$

According to the classical testing system, the answer given after the expiration of time is considered incorrect:

$$\delta(t^k \le T^k) = \begin{cases} 1, & \text{if } t^k \le T^k; \\ 0, & \text{otherwise.} \end{cases}$$

In this case, it is impossible to fully appreciate the student's knowledge, taking into account several criteria, for example, the time. Often the answer, which was given with time excess, but is correct, is worth considering. To do this, it is necessary to use a penalty function that reduces the amount of points received if the time limit is exceeded:

$$r = \frac{\sum_{k=1}^{m} p_k \cdot \chi(k) \cdot (1 - \beta_k \cdot \delta(t^k > T^k))}{\sum_{k=1}^{m} p_k},$$

where $\beta_k = \beta_k(p_k)$ – coefficient that determines the amount of penalty for an untimely but correct answer. Obviously, the penalty should depend on the question complexity – if the trainee answered with a delay to a simple question, then the penalty value should be bigger comparing to penalty when the time is exceeded with a complex question. For example, such penalty value can be used: $\beta_k = \eta_k \bullet (1 - p_k)$ where η_k – predetermined normalization coefficient. For the penalty coefficient correctness, it must satisfy the following condition: $0 < \eta_k < \frac{1}{1 - p_k}$.

Moreover, often it is important to consider, how far the time threshold was exceeded. Obviously, the more time the trainee has spent, the less points he will receive for the correct answer. For example, it can be done as follows: $\delta(t^k > T^k) = \frac{T^k}{t^k}$. As can be seen, with a large time limit excess, the student gets less points for the correct answer.

Thus the original formula takes the following form:

$$r = \frac{\sum_{k=1}^{m} p_k \cdot \chi(k) \cdot (1 - \beta_k(t^k)) \cdot \delta(t^k)}{\sum_{k=1}^{m} p_k},$$

where

$$\beta_k(t^k) = \begin{cases} 0, \text{ if } t^k \leq \mathrm{T}^k; \\ \eta_k \cdot (1 - p_k), \text{ otherwise} \end{cases},$$

$$\delta_k(t^k) = \begin{cases} 1, \text{ if } t^k \leq \mathrm{T}^k; \\ \frac{\mathrm{T}^k}{t^k}, \text{ otherwise} \end{cases}.$$

This formula makes it possible to evaluate the trainee's knowledge, taking into account not only the correctness of the answer, but also the time used to find it, even if the initial time limits were exceeded.

The formula for question complexity level also must be modified, taking into account several parameters:

$$p_i^j = p_i^{j-1} + f_i(p_i^0, m, d^{j-1}, Z, T_i), j = \overline{1,m}, i = \overline{1,n},$$

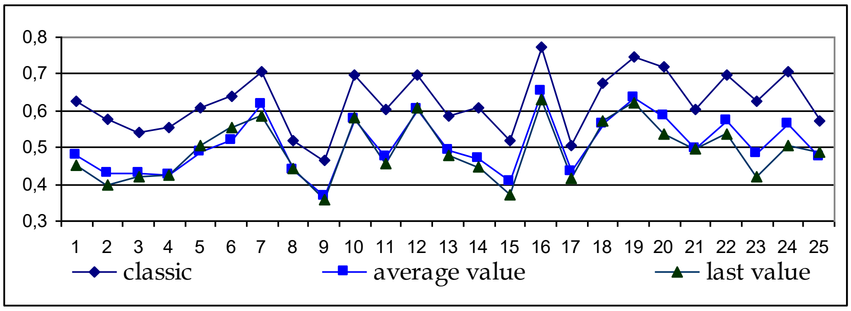
where m – the questions number, n – trainees number. In this formula also the time limit, which was set to answer the question, is used. If the answer is received in time, this parameter can be ignored, otherwise, if the answer is correct, but received with a delay, two options are possible:

- The question complexity should be reduced – if the correctness of the answer is more important than the time excess
- The question complexity should be increased – if time limit is more important than the correct answer.

Implementations of this approach results in more accurate control of the trainee's knowledge, and, more importantly, it gives opportunity to evaluate his ability to use the acquired knowledge.

4 Example of Adaptive Assessment Technology Application

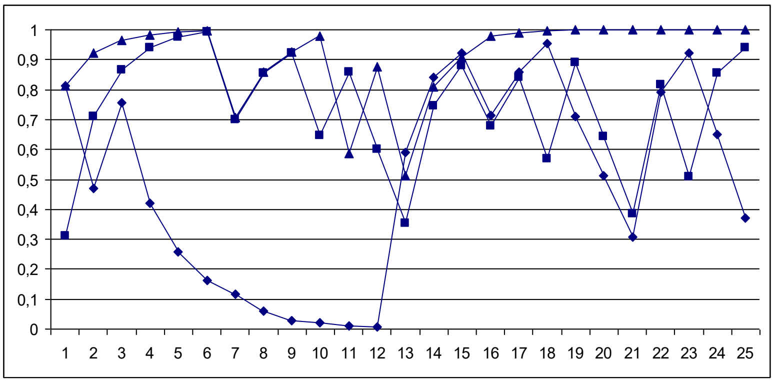
To test the method for questions complexity correcting in real time, an experiment was conducted with one group of 25 students. The test consisted of 100 questions. Before the test, the examiner had set the initial complexity of all questions to be equal $0,5$. The experiment results are shown in the figure below.



The top line corresponds to testing, using the classic knowledge assessment method, the average score was $0,623$.

The middle and bottom lines correspond to testing, using the proposed adaptive system with the initial questions complexity $0,5$. The complexity was changed according to the rules described above. After the testing was completed, the results of all the students of the group were recounted. Two variants were considered: with the final complexity (total score was $0,492$) and average complexity ($0,507$) during the testing time.

The questions complexity adaptation in real time on the example of three questions is shown in the figure below.



One of the main results of using the adaptive system is reducing the time, spent for assessment, which allows to increase the time of studying.

The proposed methodologies testing was made during assessment of six groups, it is presented below. According to the classic assessment system, the students had to answer all 50 questions. The optimized method, based on the adaptive ascending scheme [11], reduced the number of questions to 14-16 for each student. The time taken to pass the test for each of the 6 groups is shown in the table.

Group ID	Trainee's number	Classic assessment method, min.		Optimized method, min.		Relative deviation, %		Absolute deviation, point	
		A_1	A_2	B_1	B_2	C_1	C_2	D_1	D_2
1_1	29	60	62	24	27	6,7	4,2	0,201	0,126
1_2	30	77	78	28	31	4,2	5,6	0,126	0,168
2_1	32	70	75	27	25	5,1	5,8	0,153	0,174
2_2	36	75	75	25	27	5,3	4,9	0,159	0,147
3_1	36	72	76	28	30	6,5	6,1	0,195	0,183
3_2	37	80	80	28	32	6,2	6,3	0,186	0,189
Average	33,33	72,3	74,3	26,7	28,7	5,67	5,67	0,17	0,16

The average relative deviation of the estimates obtained using different schemes was $5,67\%$, or the score deviation $0,17\%$, according to the five-point rating scale.

These results indicate a significant saving of time spent on testing, with a relatively small results deviation.

In the second experiment, a multi-criteria evaluation system was used. Within 50 questions proposed, 20 had a time limit, and the time criteria were predominant in comparison with the correctness criteria. The average estimation time (A_2) increased slightly. The adaptive system applying allowed to reduce the time (B_2) to 28 minutes in average, 16-18 questions were asked each student. The increase in the questions number by the system is due to a slight increase in the number of errors made by students.

As can be seen from the tests results, the proposed systems allows to significantly improve the knowledge assessing process.

5 Conclusions

Recently, more and more research are dedicated to intelligent systems application in the education process. Almost all of them are aimed at optimizing the learning process as such, helping to determine the set of necessary disciplines or to plan the use of time correctly, but they almost do not improve the systems of students' knowledge assessing. Only few of them are aimed at an adequate comparison of the results obtained during students testing, but they do not affect the testing process itself, leaving the questions selection and determining their complexity task for teachers and examiners. Moreover, classical testing system as such does not allow to comprehensively assess the students skills level, demonstrating only their knowledge, but not the ability to use them in a difficult situation, which is very important in the modern world.

The presented adaptive assessment system allows to objectify the knowledge assessment process by correcting the questions complexity of in real time, depending on the knowledge of specific student and students in general. At the same time, results are formalized, which allows to compare the results of different groups.

Applying the multi-criteria technique makes possible to assess not only the student's knowledge as such, but also the ability to use them, to take into account the various aspects of trainee's answers, which is necessary for a comprehensive evaluation of the training results. This system allows to analyze the student's knowledge fully, to indicate possible omissions in the training for their subsequent elimination.

Furthermore, the presented models can be used not only for knowledge assessment, but also as an element of self-educational programs. For example, a similar principle at the primitive level is implemented in mobile dictionary applications: the program offers the user a set of words to test his knowledge, if multiple correct answers are given, the word is removed from the control sample, or is offered again if an error is made.

It must be noted that applying such a system requires the implementation of a large amount of verification procedures, but, at the same time, it remains simple and can be easily upgraded according to specific requirements. Its use can reduce evaluation time, which is very important when working with a large number of trainees, or with distance education, and subsequent results analysis will help to improve the education process.

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The Construction of the IRT Profiles Using Fractures that Store the Average

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Abstract. IRT profiles scheme using average interpolating polygons. The article deals with the construction characteristics of the aggregate quality of tests using average interpolating linear splines. It was found that the use of splines with free node allows to build an integral characteristic quality of compilation of tests task.

Keywords: IRT profiles of tests task, complexity of the task, differential ability, characteristic curves, splines that interpolate on average, automatic testing.

1 Introduction

1.1 Item Response Theory (IRT)

Student knowledge and skills control is one of the main elements of the learning process. The effectiveness of managing educational work and the quality of the training of specialists depends on the correct organization of the control. Through control, a "feedback" is established between the teacher and the student, which allows assessing the dynamics of learning the learning material, the actual level of knowledge, skills and abilities, and, accordingly, makes appropriate changes to the organization of the learning process. Testing is an important part of knowledge control methods. The testing system is a versatile tool for identifying students' knowledge at all stages of the learning process. In modern conditions, knowledge of testing techniques and the creation of test-bench bases is a necessary component of the teacher's work.

The use of tests as a tool for measuring knowledge implies the presence of certain quality characteristics arising from the theory of test control [3,6]. The theoretical basis for test control is the classical theory of tests and the modern theory of Item Response Theory (IRT). These theories began to emerge in the studies of the late 19th and early 20th centuries in the scientific works of F. Galton, J. Cattell, A. Binet, T. Simon, , E. Thorndike, C. Spearman, H. Gulliksen, L. Guttman, L. Crocker, J. Algina, G. Rasch, A. Birnbaum and others. The steady increase in the number of publications seeking and improving the IRT model indicates the relevance of choosing these models and their widespread use.

Classic model for profile questions (the probability of a respondent with a level of knowledge θ and a correct answer to question with the complexity no higher βj) is considered a two-parameter model of Birnbaum:

$$P(\theta_i, \beta_j) = \frac{e^{D \cdot a_j (\theta_i - \beta_j)}}{1 + e^{D \cdot a_j (\theta_i - \beta_j)}},$$

where D=1.7 is constant, is item discrimination parameter, which determines the slope of characteristic curve. The disadvantage of the model in its practical application is its non-linear dependence on the parameters, and limited "flexibility". IRT is based on mathematical models that differ in visible function $P(\theta_i, \beta_j)$. Based on these models, profiles of the complexity of the questions and the level of students' preparedness are constructed - characteristic curves. Characteristic curves of the test are the main source of information in the IRT, since all other test's scores are derived from them. Characteristic profile of the task are inherent:

1. The complexity of the task, which is determined by the student's preparedness scale at the level of probability of the correct answer $P(\theta) = 0.5$. So the complexity of the task is the median distribution of the probability of the correct answer.

2. Differential ability, which shows how good the task can distinguish students of different levels of knowledge. Differential ability is estimated by the values of the lower and upper limits. The boundaries are determined by the profile: the bottom is at the level of $P(\theta) = 0.25$ and the upper is $P(\theta) = 0.75$. This property is the level of inclination of the characteristic curve of the task in the middle part. Therefore, the higher the inclination, the better the task of the test will be able to distinguish pupils' knowledge levels.

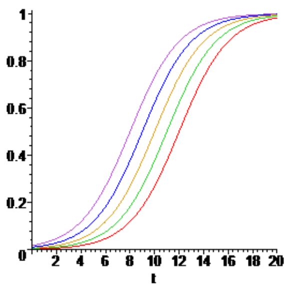


Fig.1. Characteristic curve tasks with the same differential ability, but with different levels of complexity

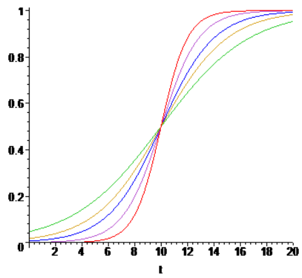


Fig.2. Characteristic curves of tasks with the same level of difficulty, but with

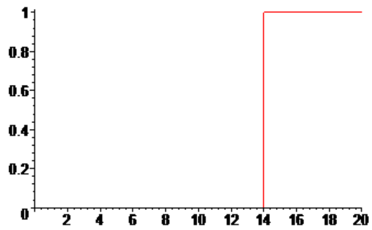


Fig. 3. Characteristic of the task with ideal differential ability

The number of mathematical models in the IRT is constantly increasing, their review appears in scientific periodicals. The reason for this is, first of all, considerable interest in the issues of assessing the quality and reliability of tests in education, as well as the need for the most accurate, reliable and easy to use model. Justifying the disadvantages of parametric models, J. Ramsey, M. Abrahamovich, S. Winsberg, D. Thyssen and G. Weiner (J.O. Ramsay, M. Abrahamowicz, S. Winsberg, D. Thissen, H. Wainer) proposed methods for evaluating characteristic curves that based on the use of spline model [1, 2]. It should be noted that the use of interpolation splines does not always correctly reflect the real characteristics, therefore, it would be advisable to consider spline models based on other approximation models, as in works I. Shelevitsky proposed to use spline regression models [4, 5]. In this paper, as an IRT model, it is suggested to use splines that store the mean of functions, that is, interpolate on average.

2 Methodological Approach

2.1 Preliminaries

Consider the supporting results that are needed in the future.

We denote by $S_r(\Delta_n)$ the set of all polynomial splines of the order r of the minimum defect by partition of $\Delta_n = \{0 = t_0 < t_1 < \ldots < t_n < T\}$, that is, the set of all functions with a continuous $r-1$- th derivative that coincide on each of the intervals (t_{i-1}, t_i) with an algebraic polynomial of degree not higher r.

If for a continuous function $x(t)$ such that there exist

$x^{(\nu)}(z)(z=0,T,\nu=0,1,\ldots,(r-1)/2)$ the spline $s_r(x,\Delta_n,t)\in S_r(\Delta_n)$ is such that for odd r

$$s_r(x,\Delta_n,t_i)=x(t_i),(i=0,1,\ldots,n),$$

$s_r^{(\nu)}(x,\Delta_n,z)=x^{(\nu)}(z)(z=0,T,\nu=0,1,\ldots,(r-1)/2)$, and for paired r, if $t_{i+1/2}=(t_i+t_{i+1})/2,(i=0,1,\ldots,n-1)$ fulfills the conditions of

$$s_r(x,\Delta_n,t_{i+1/2})=x(t_{i+1/2}),(i=0,1,\ldots,n-1),$$

$s_r^{(\nu)}(x,\Delta_n,z)=x^{(\nu)}(z)(z=0,T,\nu=0,1,\ldots,(r-2)/2)$, then it is assumed that the spline interpolates the function $x(t)$ in the nodes of the partition Δ_n, if the equality

$$\frac{1}{h_i}\int_{t_{i-1}}^{t_i}\tilde{s}_r(x,\Delta_n,t)dt=\frac{1}{h_i}\int_{t_{i-1}}^{t_i}x(t)dt$$

is performed, such a spline interpolates on average or is one that preserves the average value of the function $x(t)$.

Theorem 1. Let $x(t)$ be a function that integrates on R^1 and $X(t)$, the antiderivative $x(t)$ is such that $X(0)=0$. In addition, let $s(X,t)$ be a spline that interacts $X(t)$ in nodes t_i $0\le t_0<t_1<\ldots<t_{n-1}<t_n$, that is

$$X(t_i)=s(X,t_i)(i=0,1,\ldots,n) \tag{1}$$

Then spline $s'(X,t)$ preserves the average value of the function $x(t)$ on the $[t_i,t_{i+1}]$ interval.

Proving. Consider the relationship

$$\int_{t_i}^{t_{i+1}}x(t)dt-\int_{t_i}^{t_{i+1}}s'(X,t)dt=\int_{t_i}^{t_{i+1}}(x(t)-s'(X,t))dt=\int_{-\infty}^{\infty}(x(t)-s'(X,t))\chi(t,t_i,t_{i+1})dt, \tag{2}$$

where

$$\chi(t,a,b)=\begin{cases}1, & t\in[a,b],\\ 0, & t\notin[a,b],\end{cases}$$

Heaviside step function. Apply to (1) integration by parts

$$\int_a^b udv=uv\Big|_a^b-\int_a^b vdu,$$

let

$$u(t)=\chi(t,t_i,t_{i+1}) \text{ and } dv(t)=(x(t)-s'(X,t))dt,$$

then

$$du(t)=(\delta(t-t_i)-\delta(t-t_{i+1}))dt$$

Where $\delta(t)$ delta function of Dirac and

$$v(t)=\int_0^t(x(\tau)-s'(X,\tau))d\tau=\int_0^t x(\tau)d\tau-\int_0^t s'(X,\tau)d\tau=X(t)-s(X,t).$$

Then

$$\int_{t_i}^{t_{i+1}} x(t)dt - \int_{t_i}^{t_{i+1}} s'(X,t)dt = \left(X(t) - s(X,t)\right)\chi(t,t_i,t_{i+1})\Big|_{t_i}^{t_{i+1}} -$$

$$- \int_{t_i}^{t_{i+1}} \left(X(t) - s(X,t)\right)\left(\delta(t-t_i) - \delta(t-t_{i+1})\right)dt.$$

Given that

$$\left(X(t) - s(X,t)\right)\chi(t,t_i,t_{i+1})\Big|_{t_i}^{t_{i+1}} = \left(X(t_{i+1}) - s(X,t_{i+1})\right) - \left(X(t_i) - s(X,t_i)\right)$$

then from condition (1) we have

$$\left(X(t) - s(X,t)\right)\chi(t,t_i,t_{i+1})\Big|_{t_i}^{t_{i+1}} = 0 .$$

In addition, because

$$\int_{t_i}^{t_{i+1}} \left(X(t) - s(X,t)\right)\delta(t-t_i)dt = X(t_i) - s(X,t_i)$$

and

$$\int_{t_i}^{t_{i+1}} \left(X(t) - s(X,t)\right)\delta(t-t_{i+1})dt = X(t_{i+1}) - s(X,t_{i+1})$$

then from the condition of interpolation (1) we have

$$\int_{t_i}^{t_{i+1}} \left(X(t) - s(X,t)\right)\left(\delta(t-t_i) - \delta(t-t_{i+1})\right)dt = 0.$$

Thus, $\int_{t_i}^{t_{i+1}} x(t)dt = \int_{t_i}^{t_{i+1}} s'(X,t)dt$, that is, spline $s'(X,t)$ preserves the average value of the function $x(t)$ in the interval $[t_i, t_{i+1}]$ in other words, is interpolated on average.

From the results of work [7] it is not difficult to get the next result.

Theorem A. Let $\alpha = 2/7, \gamma = 0.2\alpha + 3$, then for an arbitrary function $x \in C^4$, the sequence $\left\{\Delta_n^*\right\}_{n=1}^{\infty} = \left\{\left\{t_{i,n}^*\right\}_{i=0}^{n}\right\}_{n=1}^{\infty}$ defined by the conditions

$$\int_0^{t_{i,n}^*} \left(\left|x'''(t)\right| + \frac{1}{n^\gamma}\right)^\alpha dt = \frac{i}{n}\int_0^T \left(\left|x'''(t)\right| + \frac{1}{n^\gamma}\right)^\alpha dt\left(i = 0,1,\ldots,n\right) \tag{3}$$

will be asymptotically optimal for interpolation parabolic splines

$$\left\|x - s_2\left(x,\Delta_n^*\right)\right\|_2 = \inf_{\Delta n}\left\|x - s_2\left(x,\Delta_n^*\right)\right\|_2\left(1 + o(1)\right) =$$

$$= \frac{\Theta}{n^3}\left\|x'''\right\|_\alpha\left(1 + o(1)\right), \Theta = \left(\int_0^1 \left(\theta(t)\right)^2 dt\right)^{1/2},$$

$$\theta(t) = \frac{1}{24}t^2(1-t)^2.$$

In the case when x''' can equal zero to only the finite number of segments (which is quite a natural condition for many real tasks, including for the purpose of our study), the conditions for choosing nodes can be simplified

$$\int_0^{t_{i,n}^*} \left|x'''(t)\right|^\alpha dt = \frac{i}{n}\int_0^T \left|x'''(t)\right|^\alpha dt \left(i = 0,1,\ldots,n\right).$$

Using the theorem and theory 1, we immediately get the following relation.

Theorem 2. Let $x \in C^3$ be such that x''' can equal zero to only a finite number of segments and a sequence $\left\{\Delta_n^*\right\}_{n=1}^\infty = \left\{\left\{t_{i,n}^*\right\}_{i=0}^n\right\}_{n=1}^\infty$, defined by

$$\int_0^{t_{i,n}^*} \left|x''(t)\right|^\alpha dt = \frac{i}{n}\int_0^T \left|x''(t)\right|^\alpha dt \left(i = 0,1,\ldots,n\right) \qquad (4)$$

and $s_2(X, \Delta_n^*)$ as a parabolic interpolation spline for $X(t)$, where $X(t)$ is the initial $x(t)$ such that $X(0) = 0$. Then $\tilde{s}_1(x, \Delta_n^*) = s_2'(X, \Delta_n^*)$ is a broken (spline of a minimal defect of order 1), which preserves the mean value of the function $x(t)$, and the partition Δ_n^* is asymptotically optimal.

2.2 Construction of IRT Spline Profiles

Let's turn to the main results of this research. Consider the process of forming respondent responses to test questions. In this case, we have two a priori unknown values that characterize the test question and the respondent, namely, the level of difficulty of the question and the level of knowledge of the respondent. If one of the parameters θ or β is locked, the evaluation task $P(\theta,\beta)$ reduces to the determination of dependence on one of the parameters: $P(\theta)$ - question profile, or $P(\beta)$ - profile of the respondent. Let's assume that θ and β in the experiment process (testing) remain unchanged, then one can find probability estimates associated with θ and β. Assume that the result of the response of the *i*-th respondent to the *j*-th task is equal to $r_{i,j}$, where $r_{i,j}=1$, if the answer is correct (but we can use a weighted estimate of $r_{i,j}>0$), in the opposite case, is 0.

$$\hat{\theta}_i = \frac{1}{M}\sum_{j=1}^M r_{i,j},$$

and the assessment of the difficulty level of the test is equal

$$\hat{\beta}_i = 1 - \frac{1}{N}\sum_{i=1}^N r_{i,j},$$

where M is the number of test tasks and N is the number of respondents.

Given that a respondent with a higher level of knowledge is correct on probabilities with probability no less than a respondent with a lower level of knowledge, we have

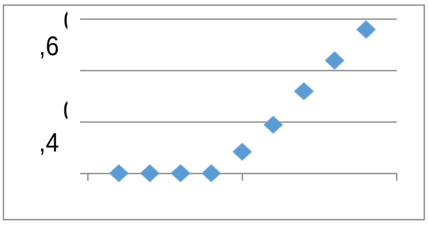
$$P(\theta_i) \geq P(\theta_k), \text{ if } \theta_i > \theta_k.$$

This implies the non-declining nature of the $P(\theta_i)$ dependence for a fixed level of complexity of the question β. That is, $P(\theta_i,\beta)$ is the characteristic profile of the task. Proceeding from this, $P(\theta_i,\beta)$ is a cumulative probability curve, each point of which corresponds to the probability that the respondent with a knowledge level not greater than θ gives the correct answer to the question with the level of complexity β. Thus, the estimates of the characteristic curve of the question are defined as

$$P_j(\theta) = \frac{1}{N}\sum\{r_{i,j}|\theta_i \le \theta\}.$$

Since we have only a set of $\hat{N}$ ratings θ, we obtain $\hat{N}$ empirical points

$$\hat{P}_j(\theta_k) = \frac{1}{\hat{N}}\sum\{r_{i,j}|\theta_i \le \theta_k\}, k = 1,\ldots,\hat{N}.$$



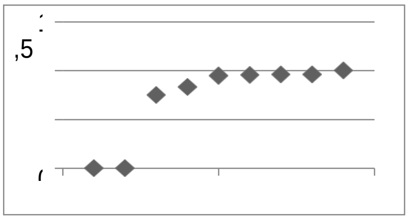


Fig.4.Behavior $\hat{P}_j(\theta_k)$ for various test tasks I and II.

Here is an algorithm for constructing an IRT spline profile, which stores an average value.

Let there be a plural $\hat{P}_j(\theta_k), k = 1,\ldots,\hat{N}$. We denote by

$$I\left(\hat{P}_j(\theta_k)\right) = \frac{1}{\hat{N}}\sum_{\nu=0}^{k}\hat{P}_j(\theta_\nu), k = 1,\ldots,\hat{N}$$

the discrete analogue of the antiderivative $\hat{P}_j(\theta_k)$.

We denote by $S\left(I\left(\hat{P}_j(\theta_k)\right), t\right)$ the parabolic spline of the minimal defect with two free nodes $t_1, t_2 \in (0,1)$, such that it is determined by the conditions

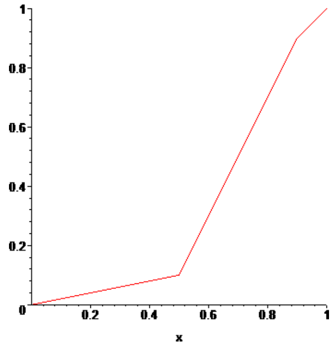
$$S\left(I\left(\hat{P}_j(\theta_k)\right), 0\right) = 0, \quad S'\left(I\left(\hat{P}_j(\theta_k)\right), 0\right) = 0,$$

and the nodes t_1, t_2 are determined by the conditions (4), where $X = \hat{P}_j(\theta_k)$.

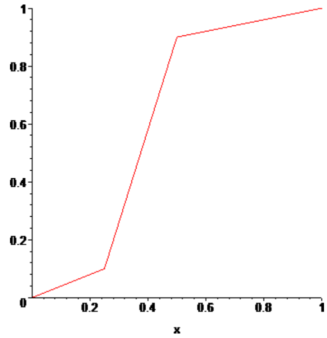
According to Theorem 2, the derivative $S'\left(I\left(\hat{P}_j(\theta_k)\right), t\right)$ s a linear spline, which preserves the mean value.

The nodes of the optimal partition $\left(t_1, S'\left(I\left(\hat{P}_j(\theta_k)\right), t_1\right)\right)$ and $\left(t_2, S'\left(I\left(\hat{P}_j(\theta_k)\right), t_2\right)\right)$ characterize the behavior of the IRT profile. The smaller the value of $|t_2 - t_1|$ and more $\left|S'\left(I\left(\hat{P}_j(\theta_k)\right), t_2\right) - S'\left(I\left(\hat{P}_j(\theta_k)\right), t_1\right)\right|$, the better the differential function of the problem, the higher the value of , the greater the complexity of the task. The ideal task meets the conditions 1t $t_1 = t_2 = 0.75$ and $S'\left(I\left(\hat{P}_j(\theta_k)\right), t_1\right) = 0, S'\left(I\left(\hat{P}_j(\theta_k)\right), t_2\right) = 1.$

So for $\hat{P}_j(\theta_k), k = 1,\ldots,\hat{N}$ we have



For the test task I (see Fig. 4-I)



for the task II (see Fig. 4- II)

Thus, an aggregated characteristic is obtained, by which it is possible to automate the process of assessing the quality of test tasks and to analyze the complexity of a particular test task (as in the example given in Fig. 4, task I is compiled rather qualitatively, and the task II is too simple).

3 Conclusion

Using an IRT model based on splines that interpolate on average allows to obtain an aggregate characteristic of the assessment of the quality of test tasks, which allows for automatic testing of test quality.

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Curriculum Optimization by the Criteria of Maximizing Professional Value and the Connection Coefficient of Educational Elements, Using Software Tools

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Abstract. In the article, the process of designing a curriculum is formalized. The structure of the curriculum for the training of specialists is proposed as a set of structural-logical schemes and a set of educational elements. The filling of the developed structural-logical scheme by educational elements allows: to clearly define the content of the educational material and the purpose of training; to provide a clear logical sequence of educational disciplines; to use the automated presentation of the structure of the curriculum. The method for improving the structure of the training curriculum by the criterion of the general significance of educational disciplines content modules has been developed. The informational system for improving the structure of the curriculum of training according to the criteria of general significance has been developed.

Keywords: Curriculum optimization, Curriculum development, Vocational training.

1 Introduction

The main purpose of universities is to produce well-qualified specialists. At the same time, the quality of the training of specialists depends on how well the graduate can meet the modern workplace requirements. The quality of specialist's training is largely determined by his course. The training of professionals that meet modern demand entails the continuous improvement of educational programs. Therefore, the curriculum must be flexible enough to quickly adapt to changing requirements [1, 2].

Currently, the process of designing a curriculum is based on the experience and intuition of university staff, therefore it needs improvement and scientific evidence/support for the decisions made.

The development of modern technical and software, methods of constructing decision support systems makes it possible to improve the efficiency of work in educational institutions through the introduction of modern methods for processing information [3], construction and implementation of mathematical methods and models, tools for the search, analysis, formation and optimization of managerial decisions [4, 5].

The problem of automating curricula designing was considered in many scientific papers. How to optimize the logical structure of curricula based on the apparatus of graph theory was considered in the following works [6, 7, 8]. Improvement of making curricula of higher educational institutions using hierarchical trees of specialist training purposes was considered in the work [9]. In the work [10] algorithms of curricula improvement based on relationships between modules were proposed.

Scientific publications devoted to the optimization of curricula, considering the necessary condition that the volume of modules should be equal to the volume of the curriculum [11]. The problem of optimization the logical structure of curricula on the basis of the theory of graph apparatus, was considered in works [6, 7]. Improving the compilation of curricula of universities using hierarchical trees for the purposes of specialist training was considered in the works [9]. Algorithms of optimization of curricula on the basis of relationships between modules were offered in work [10]. It should be noted that most works fix only the presence or absence of relationships between modules.

Analysis of works on optimization of curricula [6, 9, 11, 12] showed that the main methods of optimizing curriculum include: matrix method, graph method, method of constructing tree of targets.

According to I. M. Morgunov [6], J. Johnson [7], the development of the structure of the curriculum should be based on the theory of graphs and matrix methods. The authors propose, first of all, to establish the logic of the learning, that is, the order of studying the training modules, based on the graph of module's connectivity. For each content module, the time period for a possible study is determined. Then the modules are distributed on weeks according to the chosen optimization criterion.

A. Moskvychenko [9] proposes to improve the structure of curricula with the help of hierarchical trees for the purpose of training a specialist. Target Tree has several hierarchical levels. Main goals of the training are graduate's knowledge and abilities. Each goal is put in accordance to one or more disciplines of the curriculum. Each discipline can be divided into modules. The educational process tree of goals has three levels: the goals of the educational process; blocks of curriculum disciplines; thematic modules of discipline. Thematic modules have equal amount of time.

The inputs are the coefficients of the relative importance of the goals for the educational process, as well as the importance of the second level objectives for the objectives of the first level. Based on these data, the coefficients of the relative importance of the goals of the second level, the importance of the goals of the third level for the purposes of the second level and the ratios of the relative importance of the objectives of the third level are calculated. The modules are placed by the reduction of group weights. It is necessary to select in the curriculum V of the first modules, where V - the volume of the curriculum in the modules. Then an expert survey is conducted to establish relationships between the selected modules in the curriculum.

Such an algorithm does not take into account the relationships between the modules. The relationships between the modules included in the curriculum are evaluated after the content is selected. Therefore, in the process of designing a curriculum, there may be a lack of information for students to master the teaching material of some modules, since the modules required for them as an information base may have insufficiently high group weight.

In the works of E. Herman [12], A. Ovchinnikova [11] algorithms of optimization of curricula on the basis of the graph method are proposed, taking into account the relationships between the content modules. In these works, optimization of the plan is possible provided that the total volume of the modules of educational disciplines is equal to the scope of the curriculum. And only the presence or absence of relationships is noted.

In work O. Trofimova [10] highlighted the possibility of improving the curriculum by several criteria, taking into account the density of the relationship between the modules and the significance of each module, but the algorithm built by the author does not allow to take into account the dual vocational training of future engineers-teachers.

The peculiarity of curriculum designing in engineering and pedagogical higher educational institutions is associated with the direction of the professional training at two sites of the activity: professional training and engineering activities. In the work [13] it is stated that the training of specialists for engineering and educational activities should take into account engineering and teaching components, moreover these components must be interlinked and integrated, that is to make a dual system.

Thus there is a need to develop a qualitatively new approach to design a curriculum for future engineers-teachers of computer profile built on the model of dual content of engineers-teachers' training.

2 Formalization Contents of Training

We will formalize the process of designing a curriculum for the training of engineers-teachers of the computer profile. The curriculum is a set of disciplines that are interrelated and must be studied over a certain period of time. The structure of the educational material of the discipline consists of smaller elements - modules.

$$ZD=\left\{ZM_1, ZM_2, ..., ZM_j, ..., ZM_L\right\} \quad (1)$$

where *ZD* - content of the discipline;

ZMj - *j*- content module of discipline;

L - number of modules in the discipline.

The number of modules for each discipline varies and depends on the volume of discipline.

Each module consists of single elements - educational elements. Educational element is the minimum dose of educational information that preserves the properties of the training object. Educational elements can be represented in the form: concept, phenomenon, relation, and algorithm.

$$ZM=\left\{N_1, N_2, ..., N_j, ..., N_t\right\} \quad (2)$$

where *Ni* – *i*-educational element of the module.

Since one educational element can belong to different content modules of different disciplines, it is advisable to design the training of a specialist as a set of objects of the lowest level - educational elements.

$$N = \left\{ N_1, N_2, ..., N_j, ..., N_g \right\} \tag{3}$$

where N - content of specialist training, Ni - educational element.

To structure the dual content of the professional training of engineer-teachers, we will use the graph method [14]. The structural-logical scheme of professional training of future engineers-educators should be represented in the form of a graph whose vertices are educational disciplines, fig. 1

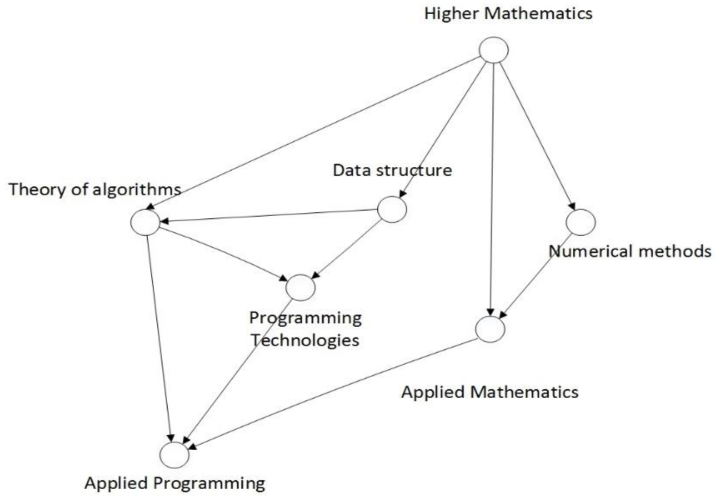

Fig. 1. Fragment of the content graph of the training

We will analyze the discipline for the presence or absence of mutual relationships between the teaching elements. Disciplines between which there is no connection we shall isolate into layers [14]. A group of disciplines joined by a layer will compile a list of disciplines for the academic semester.

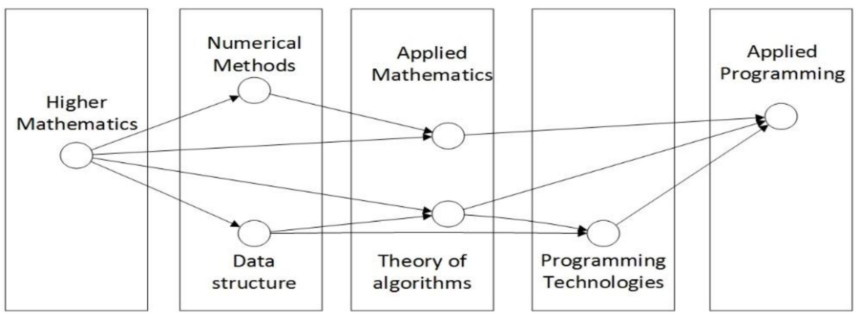

Fig. 2. Fragment of the structural-logical scheme of training engineers-teachers of the computer profile is divided by layers

In fig. 2 shows a fragment of a structural-logical scheme structured in layers. Thus, part of the curriculum is depicted in Fig. 1. can be represented by five layers. Therefore, these disciplines will be studied within five semesters.
The combination of the graph and set of educational elements form components for content model of specialist's training. This model allows to:

- clearly define the content of educational material and learning goals;
- to present the content in a clear and foreseeable manner;
- involve experts in discussion about the completeness and target indicators at the initial design stage;
- ensure the logic of teaching;
- go to computerization of presentation of the content model;
- form a systematic notion of the content of educational material.

3 Mathematical Formulation of the Problem

The process of forming a training plan for future engineer educators should take into account the high dynamics of the development of information and communication technology. This is possible due to the principles of modular selectivity and modular redundancy. The principle of modular selectivity lies in the fact that in each discipline there is a certain part of important modules, which must necessarily constitute the content of vocational training, the so-called invariants of disciplines. The principle of modular redundancy is the ability to form discipline with a large number of related modules. Compliance with these principles allows you to adapt the curriculum to the requirements of the present and provide the most effective professional training.

Thus, when forming a curriculum we will consider two types of modules. Normative modules - modules that are required to study and fall into the curriculum. The number of these modules should not exceed the maximum number of modules *L* for this discipline. Variant modules - modules that may not fit into the curriculum.

The task of improving the curriculum is to select the most important for the professional activity of the material and place it in semesters in an optimal way.

The modules of the curriculum are interconnected that is in the following ones the material from the previously studied modules is used. If the module *Mi* uses information from the module *Mj*, *Mj* is called an ancestor relative to *Mi*, *Mi* is called a descendant relative to *Mj*.

Density of connection *P (i, j)* between the modules *Mi* and *Mj* may be characterized, considering which part of the module *Mi* is used in the material of module *Mj*.

$$P_{(i,j)} = k_1 * k_2 \tag{4}$$

where *k1* – the number of study elements used in the module of *Mj* descendant of the module *Mi*;

k2 – the number of these connections.

After evaluating all connections of all modules the density of communications is normalized from 0 to 10. In determining the coefficient of module significance for study of further material we will take into account not only the module contribution to the study of its direct descendants, but also the later studied modules. For this purpose let's enumerate all the modules, giving one index to each. Let the number of modules be *M*. Then the graph of connectivity can be provided by a two-dimensional matrix *A* of *MxM* dimension, each element of which is *a (i, j)*, which is equal to the density coefficient of communication between modules *i* and *j P (i, j).*

Introduce the concept of iterative power of *k* order of m – $p^k(m)$ module. Iterative power of *m* module of the first order characterizes the value of the contribution of a module-ancestor to explore its descendants and is equal to the sum of weights of connections that go from it.

$$p^1(m) = \sum_{i=1}^{M} a(m,i) \tag{5}$$

where $a(m,i)$ – coefficient of density connection of module-ancestor with the module-descendant.

Iterative power of module of the second order describes its contribution to the study of its descendants and the descendants of the second generation

$$p^2(m) = p^1(m) + \sum_{i=1}^{M} p^1(i) \times P(m,i) \tag{6}$$

Usually just a few iterations to rank all the elements of the matrix are needed. After the ranking of the elements ceases to change, one can finish the calculation. Note through k_c the significance coefficient of module for the further material study.

$$k_c = \frac{p^{\max}(m)}{\sum_{i=1}^{M} p^{\max}(i)} \tag{7}$$

The significance coefficient for the further study of the material – descendants comes to the scale from 0 to 10.

Construction of the curriculum is based on the data obtained from experts. In the training process of engineers-teachers of computer profile it is important to consider the educational component of each engineering module and the engineering component in each pedagogical module. Therefore, the task of experts is to determine for each module the coefficient of significance for the future activity of computer systems engineer and the coefficient of significance for the future activity of a teacher.

In this study, special attention was given to criteria weighting, considering the influence of weight assignment on the final result [15].

The coefficient of professional significance is found with the formula:

$$k_{np} = \frac{1}{5} k_n + \frac{4}{5} k_i \tag{8}$$

where k_n– the average assessment of the module by experts-teachers;

k_i – the average assessment of the module by experts-engineers.

For each module the coefficient of the total value is calculated.

By solving the task of optimizing the training curriculum, we will understand the multicriterial task for maximizing the professional value and maximizing the connection [16, 17]. Let us reduce the multicriteria problem to a single criterion [18, 19].

$$k_з = 0.5 * k_c + 0.4 * k_n + 0.1 * k_i \tag{9}$$

The formation of the content in the form of a directed graph and a set of educational elements that form the maximum value of the generalized significance will be considered to be the solution for the task of optimizing specialist's training content.

4 Stages of Automation of the Design of the Curriculum of the Disciplines of Professional Training

Method of optimization of the curriculum for future engineers-teachers ~~after~~ for the criterion of maximizing the generalized significance considering the connectivity of modules consists of the following ten steps:

1. Getting expert data. Linking educational elements (data that reflects the basic educational elements for each educational element that is necessary to study). Assessment of pedagogical and engineering significance of modules.
2. Building the modules dependency graph.
3. Calculation and ranging the coefficient of density dependence between modules.
4. Removing contours. Finding the cycle in the graph and removing the edge, which belongs to the cycle and has the lowest coefficient of density dependence between modules.
5. Calculating the overall significance coefficient of the module.
6. Removing excessive modules from the graph. For each discipline compare the total number of modules and the permissible number of modules, and if there are too many modules, we remove the excessive ones, choosing the module with the lowest coefficient of general significance.
7. Building the graph of dependence between disciplines.
8. Calculating and ranking the values of density dependence coefficients between disciplines.
9. Removing the contours from the graph.
10. Dividing the contours into layers.

The algorithm for optimization of the curriculum for future engineers-teachers after the criterion of maximizing the generalized significance is presented in Fig. 3

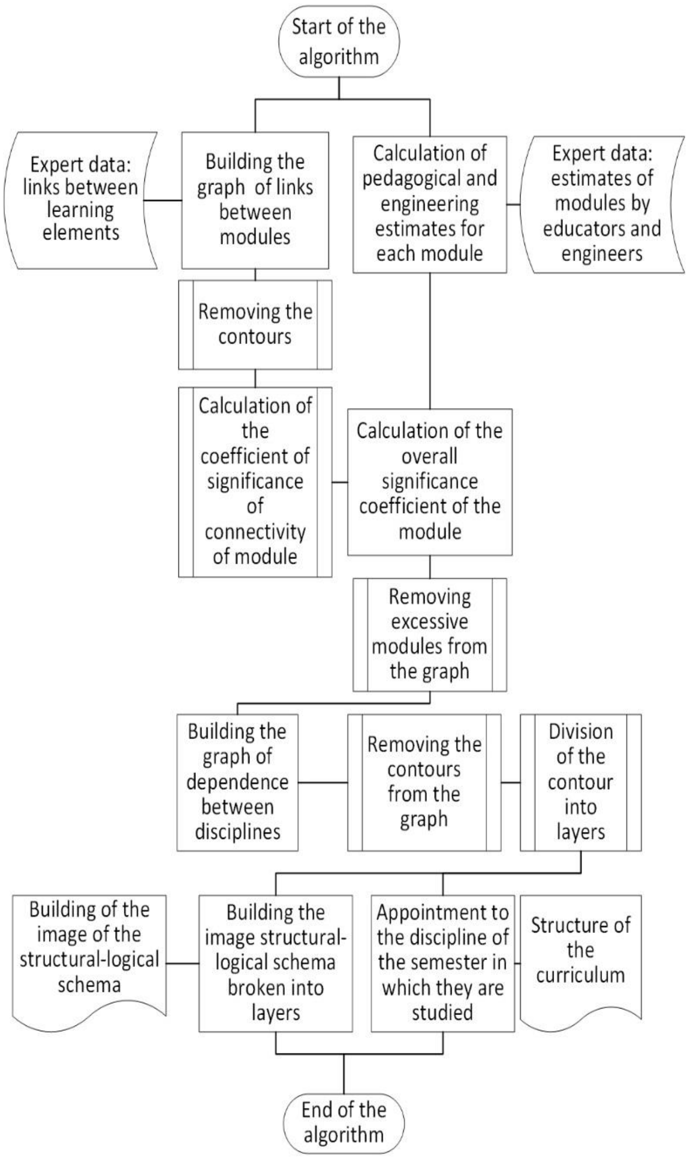

Fig. 3. An algorithm for optimization of the curriculum

Based on the described mathematical apparatus the information system of management of curriculum designing in terms of dual training was designed and implemented.

Information system is a software tool based on the use of .NET Framework and ASP.NET MVC. Microsoft SQL Server is used to store data. The MVC model is presented in fig. 4.

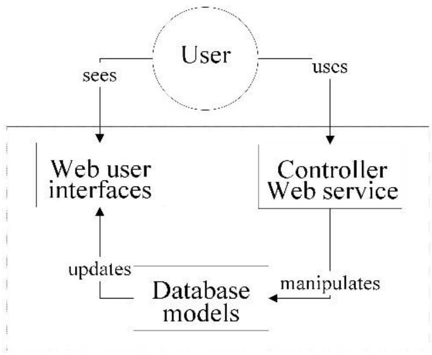

Fig. 4. MVC model

The Web service provides the following functionalities:

- authorization of users and differentiation of the rights of their access to the possibilities of the site;
- management of discipline directory: the ability to create, edit and remove disciplines;
- management of content modules directory: the ability to create, modify and delete modules;
- management of the Directory of Educational Elements: the ability to create, edit and delete educational elements;
- linking to the module of the list of learning elements studied within the framework of this module;
- linking to the learning elements of other learning elements, which are determined by the basic elements for studying this learning element;
- to make expert evaluation by engineering and pedagogical specialists of variational content modules, which are part of disciplines with an excessive number of modules;
- management of user lists: create, edit, delete users, assign roles to differentiate rights;
- processing expert data and forming a structural and logical scheme for the training;
- the isolation of the layers of the structural-logical scheme of training;
- constructing an image of a structurally-logical scheme for the training, broken down into layers.

To work with the database, we chose .NET Entity Framework, namely the Code First approach. This approach involves describing database models with the help of a program code, and from it the database is generated. As a result, we received the database depicted in Figure 5.

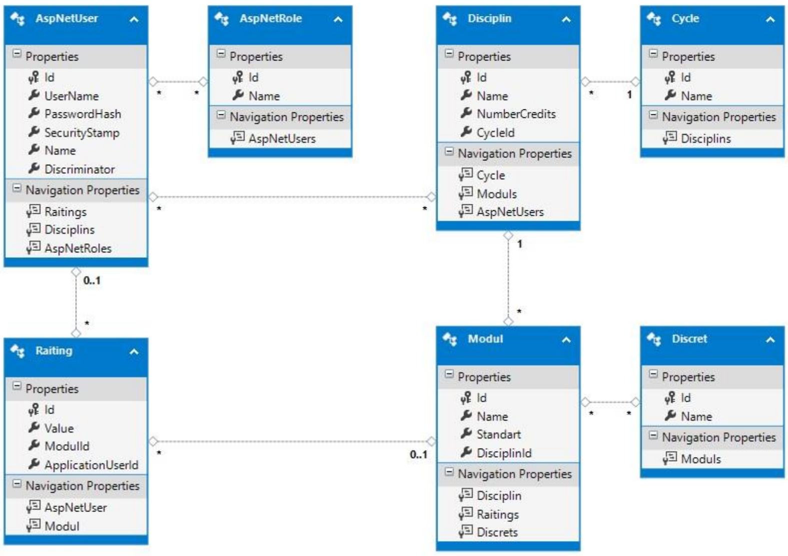

Fig. 5. Structure of the database

Now let's look at the basic classes of database models. Class "Discipline" contains information about the discipline in fig. 6.

```
Disciplin

int Id
string Name
double NumberCredits
int CycleId

public virtual Cycle Cycle
public virtual ICollection<Modul> Moduls
public virtual ICollection<ApplicationUser> ApplicationUsers

public float CalcStandartModul()
public bool CanAddStandart()
public bool IsOverfull()
public static ValidationResult ValidateNameUnique(Disciplin disciplin)
public static ValidationResult ValidateCredits(Disciplin disciplin)
public static ValidationResult ValidateAllCredits(Disciplin disciplin)
```

Fig. 6. Diagram of the Discipline class

Field Id - stores a unique object index.

Field Name - keeps the name of the discipline.

Field NumberCredits corresponds to the number of credits assigned to the discipline.

CycleId field - saves the unique key referencing to the table of cycles (Cycle).

Cycle property - the virtual field returns an object of the type Cycle (a training cycle) whose key corresponds to CycleId.

Property Moduls - returns a collection of Modul type objects (modules) that refer to this discipline.

CalcStandartModul () function returns the number of credits reserved by standard modules.

CanAddStandart () function returns true values if it is possible to attach another normative module in the discipline, the value false otherwise.

IsOverfull () function returns the true value if the number of modules is greater than the maximum value of the number of modules for this discipline, the value false otherwise.

Functions ValidateNameUnique, ValidateCredits, ValidateAllCredits - check the boundary values for the saved object to the database.

ValidateNameUnique - checks for the uniqueness of the name of the discipline.

ValidateCredits - checks that the number of credits is multiple of 0.5.

ValidateAllCredits - Does not allow you to keep discipline if the number of credits for the course is over.

Depending on the user's role ("Developer", "Expert" ("Educator" or "Engineer"), "Administrator"), "Web-site" has different functionality.

The functional capabilities of the system for the user in the role of "Curriculum developer" allow the creation and editing of disciplines, modules of teaching disciplines, educational elements, as well as establishing links between educational elements. Based on these connections, the system calculates the coefficient of connectivity between the content modules.

The functional capabilities of the system for the user in the role of "Expert" ("The teacher" or "Engineer") allow to view and edit any discipline, content module, training elements and determine the professional importance of the content modules of the disciplines. This assessment is taken into account by the system to determine the duality factor of the content module and to decide on the feasibility of including this content module in the curriculum. Depending on the role of "Teacher" or "Engineer", the professional pedagogical or professional engineering significance of the content module is determined.

The system function for the user as Administrator allows you to add, edit and delete users of the system. The administrator also has every opportunity to develop a curriculum. However, he cannot make an expert assessment of content modules.

The "Structure of the curriculum" requires the presence of Microsoft Windows Server operating system and Microsoft SQL Server database management systems. Workstations must have Web browsers and Microsoft Excel installed.

Web interface for the main page of the "Structure of the curriculum" is depicted in Fig. 7.

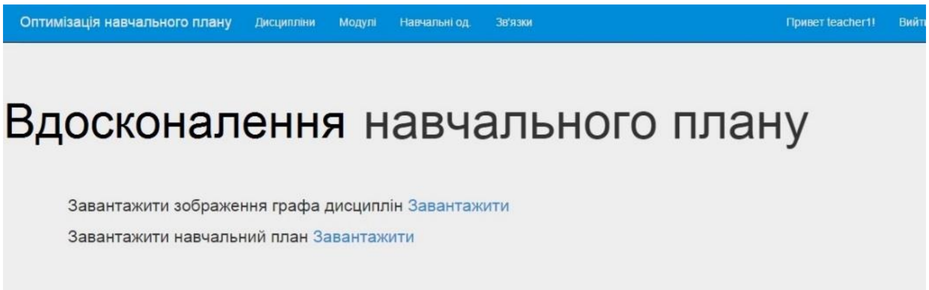

Fig. 7. Web-interface of the "Structure of the curriculum"

Inputs for the information system "Structure of the curriculum" are: a directory of disciplines, a directory of modules, a directory of educational elements, links between educational elements, expert assessment of the professional significance of each module.

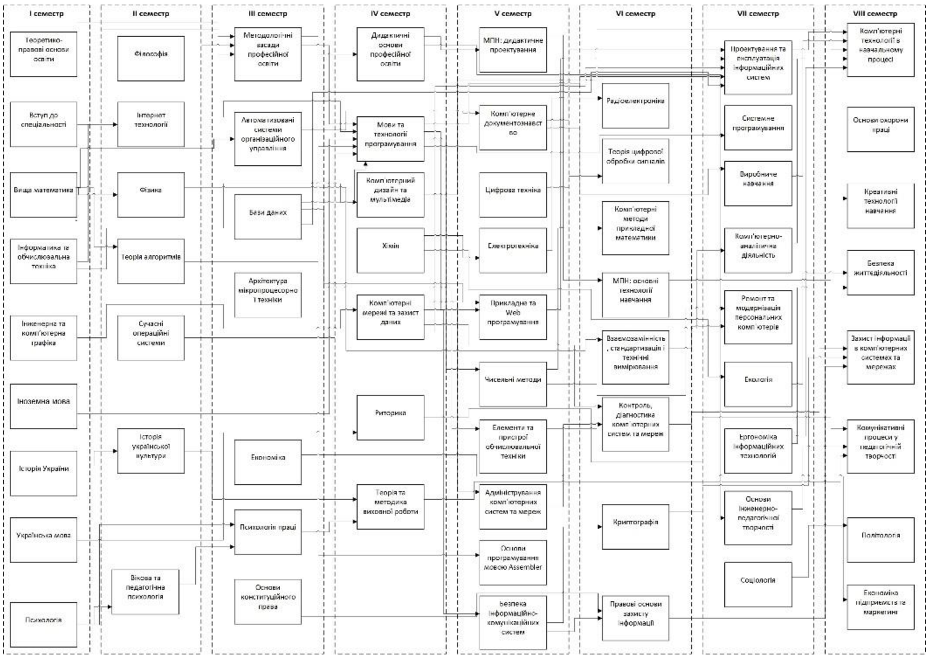

Fig. 8. The structural-logical scheme of training

Output - there are two documents: the first document - a graphical representation of the structural-logical scheme of training (Fig. 8); The second document is the Excel spreadsheet file, which contains a list of disciplines with semesters in which it is recommended to study these disciplines.

5 Conclusion

The structure of the curriculum for the training of specialists is proposed as a set of structural-logical schemes and a set of educational elements. The filling of the developed structural-logical scheme by educational elements allows: to clearly define the content of the educational material and the purpose of training; to present the contents of the educational material in a visual and accessible form; to engage experts to discuss the completeness of content and targets at the initial design stage; to provide a clear logical sequence of educational disciplines; to use the automated presentation of the structure of the curriculum; to form a system representation of the content of the educational material both from the developers and the teachers.

The method for improving the structure of the training curriculum by the criterion of the general significance of educational disciplines content modules has been developed.

The informational system for improving the structure of the curriculum of training according to the criterion of general significance has been developed. This system provides the possibility of distance work on the development of the structure of the curriculum.

With the help of the information system, the structure of the curriculum of training of the bachelor's degree in major "Professional Education. Computer Technology" is improved.

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Scientific E-conference as a Tool of Development Students Research Competence: Local Study

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Abstract. The article considers the competence approach to the formation and development of university students' research competences by means of scientific e-conferences. It analyzes the concept and structure of research competences. It establishes the compliance of the developed competences with the ISTE 2016 standard for students. It offers the indicators of measuring the acquired research competences. The present article also substantiates the efficiency of the scientific e-conferences use as an instrument for the development of students' research competences.

Keywords: E-conference, Research Competences, Standard, Open Conference Systems, Education.

1 Introduction

The key factors of changes in the educational environment of recent decades are the formation of a global knowledge economy, which comprises such features as increasing importance of high technologies and knowledge-intensive industries as well as widespread informatization. In connection with this, there arises the need for integration of education and science at the institutional, regional, and global level, since the scientific activity itself is the generator of scientific knowledge and the basis of innovation development.

The basis of meaningful changes in ensuring the compliance of education with the needs and opportunities of the society is the concept of competence approach in education [1]. Solving the problem of the integration of university education and science requires the identification and formation of special competences [2] of the participants in the educational process: both students and teachers. The emphasis on dialogue and collaboration, information technologies, which are increasingly used in the educational process of higher education, give rise to new approaches to educators and to existing forms of research. The transfer of tools and forms of scientific communication into the online space and the development of open science, which includes open data, open research, open communication, contribute to the formation of research and competences for Information and Communication Technology (ICT) Literacy [3].

Partial decisions on the training of a competent researcher in university education, which are often the subject of study of specialists in various subject areas, usually contain a quantitative assessment of the measurement of individual competences. Qualitative comprehensive assessment of the level of competence acquisition requires additional research.

The goal of the article is to find out the role of students' scientific conferences in shaping the research competence of a future specialist while applying the system of information support.

The research was carried out in the National University of Life and Environmental Sciences (NULES) of Ukraine during 2013-2017 within the framework of holding annual e-supported conferences of young scholars (for example, http://econference.nubip.edu.ua/index.php/itete/VIII/index).

2 Literature Review

The students' research work is an important component of the scientific activity of a higher educational institution and an important factor in training qualified specialists.

T. Subahan Mohd Meerah et al. with the aim of measuring the students' research skills single out such groups [4]: methodology, information seeking, problem solving, statistical analysis, communication. The instrument to measure research skills is submitted in [5].

According to A. Sirkka and J. Cap, scientific or research competence consist of various skills required to question, assess and evaluate critically, to develop scientific, research and instrumentation, organization skills to systematically collect, analyze and interpret data, to design experimental settings, to communicate in terms of scientific writing and oral presentations, and to collaborate with other actors [6].

F. Bottcher and F. Thiel have developed a research competence model, which comprises five dimensions: skills in reviewing the state of research, methodological skills, skills in reflecting on research findings, communication skills, and content knowledge [7].

Research competence are defined as the ones that enable students to analyze a given topic or subject in a structured, research-based way, often following the systematic steps in a research project [8]. The development of the student's research competence is more effective while applying mixed learning [9] and research practice [10]. The latter one often happens in the surrounding of research associations with different universities and companies.

Students aiming for a career in research and development realize at early stages that success depends not only on getting academic credentials but also on the quantity and quality of their contributions to knowledge. The most accessible way for students to get recognition for their contributions is to participate in a conference and present their findings (e.g., http://www.unica-network.eu/event/unica-student-conference-2017). The advantages of students' participation in conferences are discussed at the forums (e.g., http://blogs.plos.org/thestudentblog/2014/02/24/every-science-student-should-attend-conference/).

Many universities hold their own conference each year to celebrate the research accomplishments of their undergraduate students. They are often a place for students to present their Honors thesis project. There are also many regional and international conferences. In such cases students have more possibilities to explore the leading edge of the discipline; establishing connections in the scientific community can be of huge benefit for an undergraduate interested in embarking on a scientific career. This can help students to identify potential mentors, projects, laboratories, and institutions that they would like to work with/for in the future.

But not every student has an opportunity, first of all financially, to participate in professional scientific conferences. A partial solution to this problem is through the development of scientific online communication, in particular, conducting e-conferences [11, pp. 26-28]. The experience review of using e-conferences in higher educational institutions (HEIs) will update the following areas of research:

- the connection between asynchronous, text forms of social communication and students' perceptions of the social climate of computer conferences [14, 15]. Moderators are encouraged to seek a balance between social communications and integrated and productive discussions;
- the choice of software from a large number of tools [16] – the researches recommend the conference organizers to use available open source for efficient management of scholarly publishing activities, such as electronic acceptance of papers and abstracts, peer review of submitted papers, participants' registration, post conference proceedings and posting papers in a searchable format, and other tasks of conference management [11];
- the correlation between the participants' ICT digital literacy [12] and the quality of holding a conference. It is expected, that the participation in e-conferences promotes the development of ICT digital literacy by its participants on condition that at least 50% have Below Average level [13].

3 E-conference: Instructional Design and Realization

The student's preparation and participation in the scientific conference (Fig. 1), in our opinion, is a complex solution, which demonstrates the level of acquiring the research competences. By presenting their reports at a conference, students can gain soft-skills that will be valuable at every level of their academic careers. Students participating in a poster presentation or review must prepare a visual representation of their work and present the summary of their findings clearly and concisely to other attendees. The performance-making process requires students to organize their data and to delve into science writing at a deeper level than allowed by class lab reports. Many undergraduate science symposiums pair presenters with scientist judges who have some degree of expertise on the topic at hand. This requires the student to be well versed on the paradigms and the methods used in his or her field. The entire process of preparing and presenting a poster necessitates a significant amount of sustained effort and helps students-researchers to internalize their research and to build skills that will be useful in future.

The students in the process of preparation and participation in the conference perform the following tasks: define the subject of the report and submit it to the scientific advisor for approval; prepare the paper (thesis, article); check for plagiarism; submit for expert evaluation; elaborate; prepare the findings in the form of presentation; participate in the conference. These tasks can be grouped into 2 stages 1) preparation of paper; 2) presentation of the findings. At each stage, when performing certain activities, students acquire professional, research, information and communication competences.

The scheme of building students' research competences and their compliance with the sections of the ISTE 2016 standard is shown in Fig. 1. In particular, at each stage of the student's participation in the scientific e-conference, we will define opportunities for the formation and development of research competences. In this study, the following components of research competences are used [4, 5]: methodology skills, information seeking skills, problem solving skills, quantitative analysis skills, communication skills.

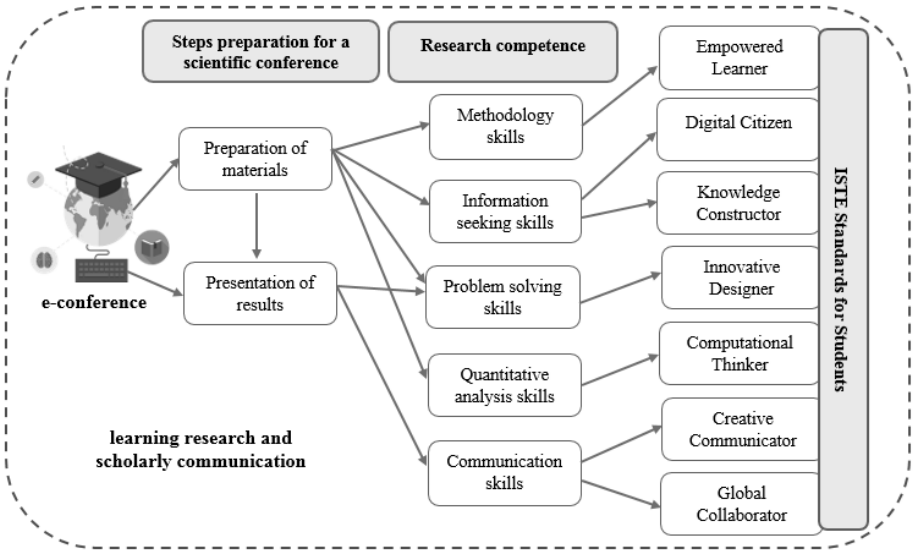

Fig. 1. The scheme of building students' research competence and their compliance with the sections of the ISTE 2016 standard (Source: Own work)

The skills that are part of the research competence structure and can be developed as a result of the student's participation in scientific e-conferences fully correspond to the "Education technology standards to transform learning and teaching (ISTE)". In particular, the definition of competences for students, their features and measurement indicators are given in [17]. This standard includes 7 components: 1) Empowered learner; 2) Digital citizen; 3) Knowledge Constructor; 4) Innovative; 5) Computational; 6) Creative Communicator; 7) Global Collaborator.

Table 1 defines in more detail the types of activities in the course of which the student develops his research competence, as well as standard indicators for students according to which it is possible to measure the level of achieving the research competence by the student for each of the above-mentioned tasks of the student's two-stage participation in the e-conference.

Table 1. The development of student's research competence in the process of preparation for the scientific conference

Task content	Activity	Components of research activities	ISTE standards and their indicators for the students
	Stage 1. Material preparation		
Formulation of the problem (according to the line of research)	- the choice of the topic; - formulation of the title; - definition of the goal, methodology of research and ways of solving the problem	- methodology skills; - information seeking skills; - quantitative analysis skills	1. Empowered Learner: 1A. 3. Knowledge Constructor: 3A. 5. Computational Thinker: 5A.
Definition of the type of scientific paper and familiarization with the requirements for its preparation	- definition of paper structure; - drawing up a plan; - selection of necessary sources of information; - choice of methods and argumentation of necessity and specificity of their use	information seeking skills; problem solving skills; methodology skills	3. Knowledge Constructor: 3A., 3B., 3C. 4. Innovative Designer: 4A. 5. Computational Thinker: 5B.
Creation of an academic paper according to the line of research (theses, scientific article)	- comparison of the data obtained during the study; - formulation of conclusions, data consolidation and generalization - preparation of the academic paper in accordance with the requirements of the conference	problem solving skills; quantitative analysis skills	4. Innovative Designer: 4D. 5. Computational Thinker: 5C. 2. Digital citizen: 2A., 2C.
Reviewing and editing an academic paper	sending a prepared paper; receiving reviewers' comments; communicating with the editor (reviewer); making a decision on introducing changes to the work	- information seeking skills; - communication skills; - problem solving skills	2. Digital citizen: 2A., 2B. 7. Global Colaborator: 7B., 7D.
Tools: communication (Outlook, Calendar, Skype, Meet, Hangouts), collaboration (One Drive, Google Drive, OneNote), cooperation (Forms, Planner), statistical data analysis (MS Excel, SPSS, PowerBI), platforms supporting scientific conferences (Open Conference Systems)			

International abstract and citation database: Web of Science, Scopus, EBSCO, Google Scholar			
Stage 2. Results presenting			
Preparation of the presentation (poster) of the speech based on the submitted academic paper	Elaboration of the speech structure and preparation of the visual demonstration in line with the requirements of the target audience	problem solving skills; communication skills	5. Computational Thinker: 5C. 6. Creative Communicator: 6C, 6D.
Tools: Cacoo, Mindomo, Power Point, Sway, Prezi, Google Presentations, Piktochart, Canva, Calameo, Youtube, Stream; platforms supporting scientific conferences (Open Conference Systems)			

Based on the analysis of publications on the management of online conferences [19], as well as on the use of online platforms for conducting student conferences [18], Open Conference Systems (OCS) – an open source software produced by multi-university Initiative Public Knowledge Project – was chosen in the NULES of Ukraine (https://web.stanford.edu/group/publicknowledge/cgi-bin/pkdrupal/about). OCS is a free web publishing tool that helps in creating a complete web presence for scholarly conferences, an integrated tool for creating a conference website, sending call for papers, electronically accepting paper and abstract submissions, posting conference proceedings and papers in a searchable format, editing papers after peer review, and registering conference participants and allowing post-conference online discussions, besides many other functions helpful to conference organizers.

The Open Conference Systems platform can support multiple conferences, and each conference. All conferences have unique URLs, as well as their own design (e.g., http://econference.nubip.edu.ua/index.php/itete/VIII/index). The system of settings allows you to assign both a single conference leader and a team for various conference calls (Table 2).

Table 2. Functions of performers in Open Conference Systems platform

Role	Functions
Site Administrator	− creating an e-conference on the site; − access policy setting; − setting up the registration of participants and assigning access according to the role distribution; − setting timing for submission of materials; − establishing types of presentation of materials; − configuring indexing options, commenting; − placing links to an e-conference on various blogs, communities, sites; − feedback setting; − configuring access to archive materials of the e-conference and commenting capabilities;

	− export list of registered persons;
Conference Organizer	− definition of conditions and format of participation; − definition of terms of submission and forms of presentation of materials; − definition of the rules of registration of participants; − definition of section moderators and reviewers
Author	− registration at the conference as an author; − loading of materials to the site (abstracts, article, presentation, poster); − making corrections after reviewing
Moderator	− appointment of reviewers according to the chosen section and the submitted material; − communication with the author and reviewer; − notification of the results of consideration of materials; − provision of the status of the submitted materials: "accepted for publication", "rejected", "recommended for revision"
Reviewer	− communication with the moderator; − reviewing the submitted materials
Participant	− registration at the conference as a participant; − commentary on performances; − review of conference materials
Reader	− search and view e-conference materials (depending on access policy)

Educators of an educational establishment or young scientists with experience in the organization of scientific conferences may be moderators of an e-conference. As reviewers can serve professionals (preferably independent) relevant to the conference. The section moderator communicates with the author of the submitted materials directly through the mailing, using the conference site, and the reviewer indirectly (through the moderator of the section), because the blind review is used.

At each stage of the preparation and participation in the e-conference the students, lecturers and experts (reviewers) cooperate in such a way as to form not only students' research competences, but also competences for ICT Literacy. Using the platform of online conferences (Fig. 2) it is possible to review the theses (2) downloaded by the students (1), to accomplish the expert assessment (3), placement (4), viewing and discussion of presentations. For other tasks it is possible to use other instruments (Table 1).

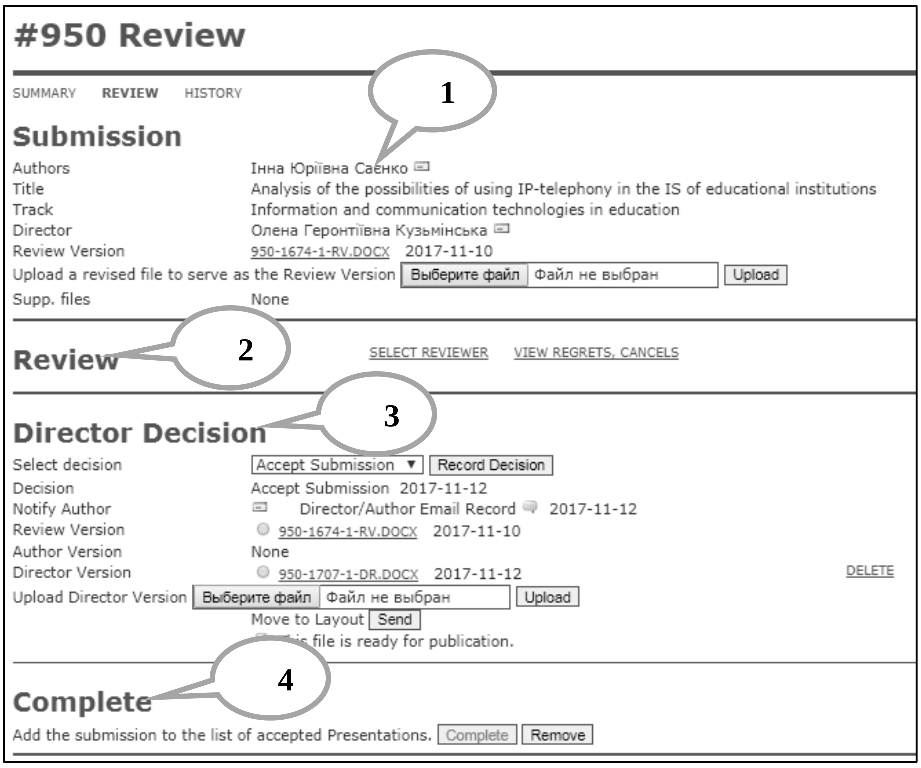

Fig. 2. An example of submitting the paper by using e-conference

4 Research Outcomes: Organization of Pedagogical Experiment, Indicators of Research Competence Measurement, Statistical Analysis

In the course of the research, a hypothesis was made that the systematic use of scientific e-conferences in the students' learning process at the University is an effective means of developing their research competence.

The research was carried out within 3 years. Students of the Faculty of Information Technologies of NULES of Ukraine were involved in the pedagogical experiment. Students of experimental groups during their training in 3, 4 and 5 years of study within the framework of the defined academic discipline were required to prepare a research paper and take part in the scientific e-conference, which was held at their Faculty (e.g., http://econference.nubip.edu.ua/index.php/itete/VIII, http://econference.nubip.edu.ua/index.php/grpi/grpi17). Thus, each student of the experimental group during 3 years of study participated in at least 3 scientific conferences. Preparation for the conference and findings of the carried out research were completed in line with the above-mentioned methods. The participation in scientific e-conferences wasn't obligatory for the students of control groups.

Questionnaires, based on previously identified research competence indicators, were developed to measure the achievement by a student of a certain level of research competence [5]. These questionnaires were used to evaluate Faculty Masters' poster sessions of the scientific conference. Out of 88 students, who submitted their diploma projects, 44 students were from the control group and 44 – from the experimental one. The examining board, consisting of professors and associate professors of the faculty, evaluated the conducted research and its presentation according to the indicators that characterize the level of research competence development by Masters. Table 3 offers examples of indicators for structural components of research competence. The 10-point scale was used to assess the achievement level of the corresponding indicator.

Table 3. Indicators for measuring research competence

Component	Indicator of research competence	Scale
Methodology (M)	M1. Understands the content of the research stages	1…10
	M2. Correctly applies research methods	1…10
	M3. Is able to substantiate methodological approaches to the research	1…10
	M4. Understands the notion of the experimental data samples	1…10
	M5. Is able to determine the hypothesis of the study, subject and object of the study	1…10
Information seeking (I)	I1. Is able to effectively seek materials on the topic of research	1…10
	I2. Uses abstract and citation database for information search	1…10
	I3. Is able to analyze and critically evaluate materials from a variety of sources	1…10
	I4. Correctly cites information sources	1…10
Problem solving (P)	P1. Is able to define the research problem and tasks for solving it	1…10
	P2. Is able to evaluate problem solving options and choose the most effective one	1…10
	P3. Can offer a new way to solve the problem	1…10
	P4. Demonstrates analytical skills to examine the consequences of a particular solution, and reasoning skills to weigh one solution against another	1…10
	P5. Demonstrates the skills of imagination and creativity while addressing the research problem	1…10
	P6. Is able to conduct scientific experiments	1…10
Quantitative analysis (Q)	Q1. Is able to carry out data collection procedures involving planning and selecting appropriate data collecting tools or instruments	1…10
	Q2. Identifies an appropriate method (quantitative and qualitative) for interpreting and manipulating data and	1…10

	Q3. Applies appropriate statistical tools for testing the research significance in addition to understanding	1…10
	Q4. Realizes limitations of analysis techniques (for example, understands the assumptions behind a statistical analysis, and examines whether your data fit these assumptions) and	1…10
	Q5. Draws and interprets appropriately the conclusions from results of analysis	1…10
Communication (C)	C1. Is able to write and present the research and its findings	1…10
	C2. Can communicate to others the purpose and outcomes of the research	1…10
	C3. Is able to summarize information, explain the purpose, objectives, conclusions of the research	1…10
	C4. Can tailor the communication to the needs and knowledge level of a particular audience	1…10

All the students from experimental and control groups were assessed on each indicator. The mean value for all indicators was taken to form the contingency table. The clustering of values was carried out on such principle: students who received an average score of 0 to 4 have a low level of research competence, from 5 to 8 – the average one, 9 and 10 – the high level respectively. Thus, the results of 3-level research competence assessment, depending on the group of students, are compiled in Table 4. It also includes the expected frequencies, provided that there are no differences between the levels of research competence in the experimental and control groups. As we can see from the analysis of the table data, the actual levels of students' research competence differ significantly from the theoretical ones: for the experimental group, the actual value of the research competence is higher than expected and vice versa.

Table 4. The contingency table of research competence levels depending on the group of students

			Levels of research competence			Total
			low	average	high	
Groups	CG	Frequency	22	16	6	44
		Expected frequency	16,5	18,5	9,0	44,0
	EG	Frequency	11	21	12	44
		Expected frequency	16,5	18,5	9,0	44,0
Total		Frequency	33	37	18	88
		Expected frequency	33,0	37,0	18,0	88,0

For statistical confirmation of the assumption that the levels of research competence differ in groups, it was offered to use the Pearson's $\chi 2$ criterion as variables belong to categorical and ordinal data types, and the Student's criterion, since it is possible to estimate the hypothesis of the equality of the mean values of two sets, in our case the means of research competence in training groups.

To test the first assumption, we formulated the null hypothesis: the use of e-scientific conferences does not affect the level of research competence, that is, the existing changes in the variable RC (research competence) are random. It was followed by the corresponding calculation, the results of which are given in Tables 5 and Fig. 3.

According to the results of calculations (Table 5), the empirical value of $\chi 2$ is greater than critical for (2-1) * (3-1) = 2 degrees of freedom: 6,342> 5.991, which also indicates the value of asymptotic value, which determines the probability of error in the rejection of null hypothesis. Consequently, we adopt the alternative hypothesis: the systematic use of e-scientific conferences affects the level of research competence, that is, existing changes in the RC variable are non-random.

Table 5. $\chi 2$ criteria

	Values	Degrees of freedom	Asymptotic value (bilateral)
Pearson's chi-squared test	6,342	2	,042
Relation of plausibility	6,454	2	,040
Linear-linear connection	5,898	1	,015
Number of valid observations	88		

Visually this is seen from a clustered diagram (Fig. 4), where we observe an increase in the level of research competence, depending on the systematic use of scientific e-conferences in the educational process.

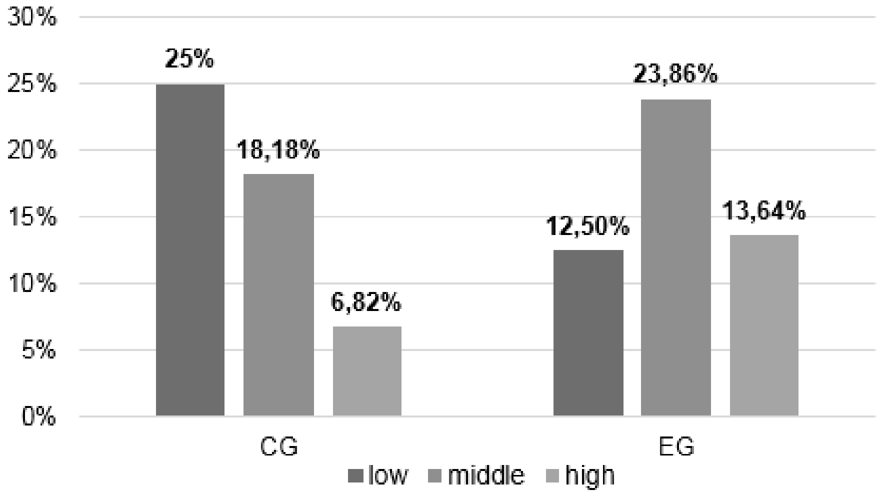

Fig. 3. Clustered diagram of research competence levels distribution in control and experimental groups

As we see from Table 6 sample mean for the control group is 5.0 points, and for the experimental group – is 6.32 (Table 6). However, to validate the differences in the sample mean for the general population, we use Student's criterion for independent samples. The actual value of t-statistics of the mean deviation is 2.415 (Table 7) with a critical tcg = 1.988.

Table 6. Group statistics

	Group	Quantity	Mean	Student's deviation	Student's error of the mean
Points	CG	44	5,00	2,597	0,392
	EG	44	6,32	2,522	0,380

Table 7. T-criterion of means equality

t	Degrees of free-dom.	Value (bilat-eral)	Means dif-ference	Student's error of the difference	95% confidence interval of difference of means	
					Lower bound	Upper bound
-2,415	86	,018	-1,318	,546	-2,403	-,233

Consequently, the hypothesis of means equality was not confirmed. Accordingly, there is a statistical difference between the mean values of the points in two groups, which indicates that for the experimental group, the mean score of the assessment on indicators of research competence is 1,318 higher than in the control group.

Thus, the hypothesis, that the systematic use of scientific e-conferences in the educational process of university students is an effective means of developing their research competence, is confirmed by the results of the pedagogical experiment and their statistical analysis.

Along with the assessment of the level of the student's research competence formation, a survey in experimental students groups was conducted according to the following three blocks of questions:

1. Personal data of the participants, in particular, the number of conferences in which the student participated, and the evaluation of the effectiveness (determining the degree of performance by a 10-point scale);
2. Evaluation of the impact of participation in scientific e-conferences on the formation of research competence individual components (the impact of each component was evaluated on a scale from 0 to 10);
3. Assessment of the influence of informational support of conferences on the formation of components of digital literacy (the development of each category of skills was assessed on a 10-point scale before and after the experiment).

Based on the analysis of the survey results, we can draw the following conclusions:

1. A student, who participated in scientific conferences each year, has a higher level of research competence (75% of students who demonstrated high and intermediate level of research competence, participated in 4 or more academic conferences).
2. Participation in the preparation of materials and presentation of research results at scientific conferences with the help of the OCS system promotes, first of all, the development of such components of research competence: Information seeking (I3),

Problem solving (P2, P4), Quantitative analysis (Q5) and Communication (C 1 -C 4) (fig. 4).

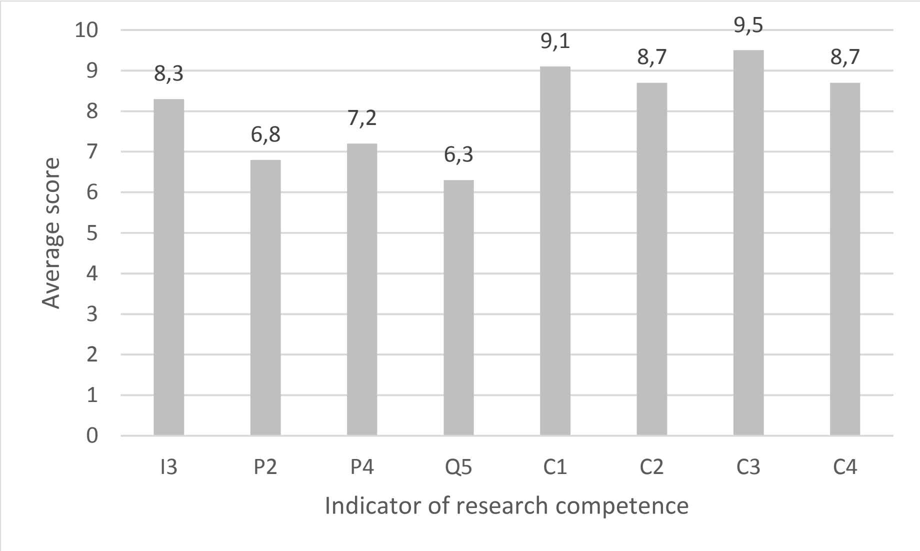

Fig. 4. Diagram of the influence of students' participation in scientific e-conferences on the development of research competence components (based on students' self-assessment)

3. According to questionnaire results, students identified the positive impact of participation in e-conferences on the development of foundational skills of ICT literacy. 85% of the respondents confirmed the increase of personal access skills, 25% – management skills, 73% – integration skills, 60% – evaluative skills, 57% –creative skills and 90% –communicative skills.

5 Conclusions

Research conferences for undergraduates give learners the opportunity to engage in formal and informal learning environments which promote their ability to engage actively and creatively in learning, research and professional communities both within and beyond the institution.

When performing each stage of preparation for participation in a scientific conference, the student finds, analyzes professional-oriented materials, searches for the optimal solution of the problem, learns to substantiate, refute false thoughts, search and analyze information, construct new knowledge and present the results of his own research and to conduct a scientific discussion. In this way, students' research competences are formed. The indicators suggested in the research for measuring research competences are an effective tool for measuring the student's achievement of the corresponding components of research competence. As a result of a three-year pedagogical experiment, students who systematically participated in scientific e-conferences demonstrated more advanced research competences while performing their Master's research papers. Moreover, the use of the platform as information support for holding e-conferences creates opportunities for equal access of students to conferences and contributes to the development of ICT literacy.

The preparation and participation in the conference covers almost all the requirements of the ISTE 2016 standard for students. This suggests that the approach, which has now been implemented in the form of systematic use of the e-scientific conferencing tool for the preparation of papers using the e-system of support for scientific conferences, takes into account, as far as possible, the requirements for the preparation of students at universities in accordance with European standards, and will make future specialists more competitive on the domestic and foreign labor market, will expand the vision and perception of the surrounding reality as of an open information system. Students also have an opportunity to explore the leading edge of the discipline, while making connections in the scientific community can be of huge benefit for an undergraduate interested in embarking on a scientific career.

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How Participation In An Intensive Project Can Increase 3rd Level Students' Awareness Of Entrepreneurship

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Abstract. Teaching entrepreneurial skills to third level students is becoming increasingly recognised as a necessary skill for them to thrive in the 21st century. Across the E.U. and globally, the teaching of entrepreneurial skills is progressively being incorporated into the core syllabus that students take during their time in third level education. However, despite the efforts of policy makers and educators, entrepreneurship is still not widespread among graduates.

This paper discusses the impact on student attitudes toward entrepreneurship of an E.U. intensive programme (called WalkAbout) that has run for the past two years. In the first year, 28% of the projects were developed further at the request of external stake holders. In the second year, 40% of the projects were developed further. In this paper we discuss the reasons as to why this programme is so successful in motivating students to further develop their projects in an entrepreneurial fashion.

Keywords: entrepreneurial learning, entrepreneurship education, project-based learning, team-based learning, game design, GGULIVRR, WalkAbout

1 WalkAbout Programme Structure

The aim of a WalkAbout project is to get students from different EU countries and different degree programmes to work in teams to create mobile games in a given context within a short period of time. The time span of the project is about ten days. During this time, the student teams are challenged with the task of building functioning GGULIVRR (Generic Game for Ubiquitous Learning in an Interactive Virtual and Real Reality) games in a given context. GGULIVRR is a concept for contextual and mobile learning games that can be built by diverse teams.

The idea of using computer games to engage and motivate students has been investigated by various other researchers. Getting students to build computer games has been shown to increase their retention of learned material. Papastergiou states that *"games constitute potentially powerful learning environments for a number of reasons (Oblinger, 2004): (a) they can support multisensory, active, experiential, problem-based learning, (b) they favour activation of prior knowledge given that players must use previously learned information in order to advance, (c) they provide immediate feedback enabling players to test hypotheses and learn from their actions, (d) they encompass opportunities for self-assessment through the mechanisms of scoring and reaching different levels, and (e) they increasingly become social environments involving communities of players"* [20]. Papastergiou also states that *"Games that encompass educational objectives and subject matter are believed to hold the potential to render learning of academic subjects more learner-centered, easier, more enjoyable, more interesting, and, thus, more effective"* [20]. Akcaoglu describes a game design and learning initiative that leverages students' interest in games and design to foster the students' problem-solving and critical reasoning skills [1]. Triantafyllakos describes how gameplay and collaborative working can help create a framework *"that meets their learning desires and expectations, incorporates and sustains technological trends such as social networking and blogging, and is harmoniously situated in the daily routine of a modern, active student with multiple interests"* [23]. Hwang describes a peer assessment-based game development approach to learning for improving students' learning achievements, motivations and problem-solving skills [12]. Hwang found that *"most of the students perceived peer assessment-based game development as an effective learning strategy that helped them improve their deep learning status in terms of 'in-depth thinking,' 'creativity,' and 'motivation."'* [12]. Ke investigated the potential of computer game making activities in facilitating design-based math learning for school children. Ke's study findings indicate that participants develop significantly more positive dispositions toward mathematics after computer game making. Ke states that *"learning occurs when the learners' active exploration (i.e., artifact design and creation) makes them develop a knowledge representation of their experience or discover an inconsistency between their current knowledge representation and their experience."* [15]. In addition, *"learning usually occurs within a social context in which interactions between learners and peers will activate collaborative exploration, articulation, reflection, and hence assimilation or accommodation for improved knowledge representation"* [15].

Entrepreneurs need to be skilled in diverse areas, such as interpersonal skills, communication, planning, leadership, management and marketing. With this in mind, WalkAbout teams are purposely comprised of students from different degree programmes and different countries. To date, students from Poland, Finland, Belgium, Ireland and Portugal have taken part in the two Walkabout projects. These students came from computing, international marketing, teacher training, visual arts, games development and business degree programmes. The students' year of study ranged from year 1 to year 3. Combining such a diverse set of students ensures that each team has the combined skillset of an entrepreneur.

The key to the success of the programme is in ensuring that the task that is assigned to the student teams requires the full engagement and buy-in of all of the team members. The teams are tasked with designing, developing and marketing a GGULIVRR game. The teams are expected to present their game prototype and business plan to a panel of invited industrial leaders at the end of the ten day programme. In order to be successful, the teams need to investigate the game context, find attractive and inviting ways in which to play the game, find and implement various software solutions, overcome hardware technical difficulties and learn to communicate effectively with their teammates so that they can optimize their collaboration. Triantafyllakos states that *"as Papastergiou (2009) claims, games constitute potentially powerful learning environments given that they: (a) support multi-sensory and active problem-based learning and critical thinking, (b) activate prior, diverse knowledge that allows the participants to successfully encounter novel situations, (c) establish meaningful collaborative learning environments which can improve students' social skills, (d) support immediate feedback which informs subsequent decision making and (e) offer opportunities for self-assessment (Kim, Park, & Baek, 2009; Oblinger, 2004; Papastergiou, 2009; Pivec & Dziabenko, 2004)"* [23].

2 Entrepreneurship

According to an EC report on the "Effects and Impact of Entrepreneurship Programmes in Higher Education", an entrepreneurial person demonstrates three key entrepreneurial competencies. These are entrepreneurial knowledge, skills and attitudes [6]. These competencies manifest themselves in the individual in the form of innovation, change and action that is essential for personal, social and work life [19]. Every entrepreneur masters a broad knowledge of business management. Entrepreneurs are very familiar with the economical, commercial, legal, social and organizational facets of business.

Entrepreneurship is now considered to be a major contributor to global economic growth [17,18]. In recent years, entrepreneurship has gained much prominence in both developed and developing nations and has thus created a higher demand for entrepreneurship education [13]. This sentiment is backed by Eickhoff who states that young people should be taught entrepreneurship education [8]. Thus, there is an increasing emphasis on education as a way to encourage entrepreneurship as a catalyst for economic development. Studdard et al. considers that entrepreneurship education will not only increase the skill levels of future entrepreneurs, but will also increase the skill levels of those pursuing non-entrepreneurial careers in the new economy [22]. Cooney states that interest and demand for entrepreneurship modules is growing among science, engineering, and arts faculties [2]. It is widely accepted that it is no longer enough to come out of third level education with a purely technical education.

At third level, entrepreneurship is widely recognized as a fundamental behavior that should be taught to students. Universities are increasingly being challenged by governments and funding agencies to expand entrepreneurship and enterprise education. This demands innovative pedagogical approaches that should be designed to stimulate and simulate the practice of entrepreneurship behaviors and the life-world of entrepreneurial firms, whilst retaining rigorous academic standards of measurement and assessment and, therefore require staff development [14]; [5]. As an example, the UK “National Council for Entrepreneurship in Education” (NCEE) has set out a number of associated competencies for students and has developed educator programmes designed to stimulate staff from any department in a third level college to develop entrepreneurial approaches to their curriculum and programme development [11]. Gibb considers that of particular importance is the simulation of the entrepreneurial life-world of ownership, intuitive decision making and risk taking, initiative taking, holistic project management, ‘know-who’ network development and relationship management and commitment over time to see things through [10].

There are various views as to how entrepreneurship can be embedded into third level teaching. According to the World Economic Forum (WEF), entrepreneurship education should comprise the following three elements [25]: personal; business development; entrepreneurial skill. According to the United Nations Conference on Trade and Development (UNCTAD), there are four key policy areas and programmes that should be considered in the development of entrepreneurship education [24]: embedding entrepreneurship into education and training; curriculum development; teacher development; and partnership with the private sector. The South East European Centre for Entrepreneurial Learning (SEECEL) states that entrepreneurial learning has two distinct strands (narrow and broad). The former is being an entrepreneur engaged in a commercial activity; the latter is being entrepreneurial [21]. The European Commission Council clarifies that entrepreneurship education should not be confused with general business and economic studies [4]. Its goal should be the promotion of creativity, innovation, and self-employment, and may include such as the development of personal attributes and skills, raising the awareness of students about self-employment and entrepreneurship as possible career options, working on concrete enterprise project and activities, and providing specific business skills and knowledge of how to start a company and run it successfully. The EACEA states that entrepreneurship education can be integrated into general education in three different ways: it can be integrated into existing subjects, it can be introduced as a separate curriculum subject or it can be implemented using a cross-curricular approach [3].

The traditional teaching approach, prevalent in many universities, is passive learning. Learners receive lectures for the majority of class time, leaving them little opportunity to give input through discussions or experiential exercises. Although very effective to cater large groups of students a large amount of learning content within a relatively small amount of time, this approach is clearly unable to engage learners into actively practice the entrepreneurial attitude and increasingly feel the rush to act and take a risk. What really distinguishes an entrepreneur is the person's attitudes and skills on how to run a business [16]. With a hands-on approach, they draw up business plans, market a product or service, propose and arrange contracts, conquer and expand market positions, lead employees and regulate daily affairs. Consequently entrepreneurship is not something one learns to understand, but something one becomes fluent in through practice. Being coached instead of lectured by their teachers, learners appreciate an environment in which creativity and risk-taking are encouraged and mistakes are valued as learning opportunities. Entrepreneurship education should focus on project based learning facilitating real life learning experiences [7]. The learners practice to be entrepreneurial by collaborating in multi-disciplinary teams, tackling concrete and tangible real-world problems. Along the way they acquire knowledge, identify and solve subset problems and learn to cooperate [9].

3 Entrepreneurship in the Partner Colleges

As is the case with many colleges within Europe and globally, efforts have been made in recent years to incorporate the teaching of entrepreneurship into the core syllabus that students take and to encourage and incubate entrepreneurship into the campus environment. Each of the partner colleges took different approaches to achieve their entrepreneurship goals, as described below.

3.1 Artesis Plantijn, Belgium

Within Artesis Plantijn, there is a specific modular programme that aims to teach students how to become successful entrepreneurs. Students learn through a series of projects how to start up a business. Entrepreneurship, enterprise policy, growth management and strategic management are intensely studied on this module.

Entrepreneurship is also embedded in the European Project Semesters (EPS). The major weight of EPS projects lies in project management and methodology. While loosely supervised, small international and interdisciplinary student teams are urged to self-organize and manage their project. Each team needs to produce an elaborate project plan, which includes role definitions, assigned tasks, a study on the project scope and preconditions, outcomes, quality control, risk analysis, a cost and benefit study and a business plan. During the semester, this plan is adjusted according to the evolution of the team and the project.

3.2 Dundalk Institute of Technology, Ireland

Dundalk Institute of Technology (DkIT) sees entrepreneurship as a key skill for students to learn. It is considered vital to link with external stakeholders and to respond to and innovate in the social and cultural environment as well as to the economy. DkIT has set one of its objectives to embed entrepreneurship into the curricula on all undergraduate programmes. DkIT has also set out to alter curricula by improving disciplinary and inter-disciplinary expertise as well as employability and personal skills. Entrepreneurship is now embedded into almost all programmes that it offers to undergraduate students.

To encourage entrepreneurial skills within students, the college has embarked on a number of initiatives, including the introduction of Student Enterprise Interns (SEIs) and the President's Awards for Enterprising Students.

On campus, the college hosts a Regional Development Centre (RDC). The RDC aims to support start-up companies in the region by providing resources such as office space, business education and expertise to help in sourcing financial aid via organisations such as Enterprise Ireland.

DkIT is the lead partner (along with five other third level colleges) on an entrepreneurship programme, which is called the "Accelerated Campus Entrepreneurship" (ACE) initiative. ACE has facilitated various Enterprise and Entrepreneurship Workshops and a Master degree level Enterprise and Entrepreneurial Learning.

3.3 Lodz, Poland

All undergraduate programs in the University of Lodz are prepared according to the Polish "National Qualification Framework". This document states that all the students have to obtain a basic knowledge and skills in the field of entrepreneurship. Students have to learn the basics of how small companies function in the economy, rules of starting enterprises in Poland and intellectual property law. Many modules are project driven. Students are encouraged to work on the commercial potential of their projects. As part of these projects, students are encouraged to work on their own ideas for new products. This approach allows student to constantly focus on creating real products. In addition, many degree theses are based on market ready products.

Innovation Center Technological Accelerator, CIAT, is an EU funded venture fund established by the University of Lodz. In the years 2013-14, CIAT organized several workshops for students in conjunction with the University of Lodz. The main idea of these workshops is to show the participants how they can transfer their ideas from different fields into projects that can apply for external financing.

The University of Lodz puts a strong emphasis on cooperation with industry. For this purpose, a Business Council was established by all faculties of the university to encourage cooperation with companies from the region. The Council consists of Polish and foreign companies that are appropriate for teaching programming (i.e. from the IT industry for computer science programme).

3.4 ISPGaya, Portugal

In ISPGaya, there are two curricular units that focus mainly on syllabus development in the area of entrepreneurship. These are the curricular units of "Technology and Business" and "Seminars of Economy and Management".

The curricular unit of "Technology and Business" offers a multidisciplinary perspective, seeking to provide students with soft skills in management and information technology. The teaching methodology adopted by this unit is based on the structuring and development of process analysis and implementation of a business opportunity from a technology based idea. Groups of students evaluate the technological, economic and financial market feasibility. They then develop a business plan that serves both as a guide for the implementation of the idea and as a document that is likely to attract investors and other participants in its future development.

The curricular unit of "Seminars of Economy and Management" offers an internal module dedicated to the teaching of entrepreneurship. This is a seminar based module. The seminars aim to provide contributions from various areas of economics and management. People of recognized merit in three major areas (business, academic and institutional environment) are invited to present at these seminars.

ISPGaya promotes an environment where private companies work in close partnership with students. The students are presented with many challenges proposed by companies during their studies. In particular, there are several curricular units that have assessment juries that are composed by people from industry. Some of those projects subsequently result in intellectual property transfer projects.

ISPGaya has a close cooperation with two technological parks located in their geographic area: InovaGaia and UPTEC. The incubation center of InovaGaia facilitates the creation and development of entrepreneurship by offering infrastructure and specialized support services. The promoters have also facilitated access to scientific and technological systems, which promotes the development of knowledge and a network of contacts with national and international markets. UPTEC is similar to InovaGaia, but offers a dedicated "Center for Business Innovation" alongside its incubator space. At the Center for Business Innovation, businesses can find the physical space, facilities and mechanisms to host and operate their project and activities. The UPTEC is dived in four distinct centers: Technology Center; Creative Industries; Sea Technology Center and Biotechnology Center.

4 WalkAbout Intensive Programmes

To date, five WalkAbout intensive programmes have taken place.

The first Walkabout intensive programme took place in Parque Biol ogico de Gaia, Portugal in April 2013. Parque Biol ogico de Gaia is a 35 hectare park that comprises woodlands and a zoological garden. A total of 40 students and 12 lecturers from Poland, Finland, Belgium, Ireland and Portugal took part in this project. During the programme, students grouped themselves into teams of five, one from each of the countries involved. Originally, eight teams of five students were formed. However, due to some local students becoming unavailable and a travelling student becoming sick, it became necessary to rearrange the remaining students into seven teams. At the end of this intensive programme, two of the seven teams (28%) were asked by the Parque Biol ogico de Gaia to develop their games further.

The second Walkabout intensive programme took place in the city of Lodz, Poland, in September 2014. A total of 28 students and nine mentors from Poland, Finland, Belgium and Ireland took part in this project. Five teams were formed. At the end of this intensive programme, two of the five teams (40%) were asked to further develop their games.

From 2014 the intensive programmes have been takin place in September in Lodz.

Both of the intensive programmes were about ten days in duration. At the very beginning of the programme, students were informed that each team would need to develop a QR code driven mobile game, which would need to be based around the context of either the Parque Biol ogico de Gaia or the city of Lodz. The students were not directed as to the focus of their game or the mechanics of their game. Students were informed at the beginning of the programme that they would need to form their own teams, subject to certain pre-defined criteria. These criteria were imposed so as to would guarantee a good spread of each nationality across the various teams. Furthermore, students were told that each team member would need to identify their role within their team and justify that role as being necessary.

Interpersonal skills are the life skills we use every day to communicate and interact with other people, both individually and in groups. From the beginning, students needed to show strong interpersonal skills in order to get placed on a team that was to their liking. Once a team was formed, interpersonal skills were needed to help individuals shape the direction that their team was travelling. This skill became particularly crucial later in the project life-cycle as the students became tired and pressurised. Teams that had one or two people who had excellent interpersonal skills were able to proceed with their projects much more smoothly than other teams.

The smooth development of a team's game relied on the ability of the team members being able to communicate effectively with each other. Team managers were tasked with ensuring that all voices on their team were heard and that all opinions counted as being equally important. Teams who communicated with each other well in the early stages of the project ended up being very solid and unified toward the more intense final stages of the project. It was very evident during the final presentations that the teams who communicated well got a huge amount of collective enjoyment from their time together working on the project. It was also clear that this enthusiasm came across to the external experts in their judging of the quality of the final presentations.

Once the teams were formed, each team had one of its members delegated as the team manager by the mentors. Technically trained students were purposely excluded from being team managers. The aim of this was to ensure that projects focused on both the creative and technical aspects of game design, rather than just the technical aspects. In some cases, the team manager stepped aside (sometimes involuntarily) and let other team members lead their team. However, the teams that had a strong team leader who took on their responsibilities in an honest and earnest way progressed more efficiently and effectively than the other teams did. Good managers showed an attention to detail and were able to organise their teams limited time effectively. Good managers were able to motivate their team to buy in to the project and to produce a very high quality of work. All four of the teams that were developed further had very strong managers.

Business planning encompasses all of the goals, strategies and actions that are required for a business to prosper. The students were required to come up with an idea, storyboard it, programme it and present it. To this end, the students were asked to make three presentations over the ten days. The first presentation, which occurred after two days, focused on the game concept and storyboard. The second presentation, which occurred after 6 days, focused on a proof-of-concept of some technical aspect of the game and on a business plan for potentially developing the game into the future. The final presentation, which took place on the last day, required the students to present their games to an invited audience of industrial and academic partners. Excellent planning was an absolute requirement in order for teams to cope with the multitude of varying tasks that needed to be performed over the ten day period. In order to do these things effectively, the team managers needed to delegate effectively. While some students were programming, others needed to be out gathering content for their games. While some students were producing presentations, others were conducting surveys with potential users. The teams that planned effectively produced more polished games and presentations.

Marketing involves promoting and selling a team's game. Marketing includes market research and advertising. Various marketing ploys were engaged by the different teams. However, the teams who really believed in their game and in their team's ability to build the game tended to produce more polished presentations. As the days went by, all of the teams became more effective at marketing their games. All of the teams became increasingly aware over the life-cycle of the project of the importance of marketing in getting an external entity to want them to fully develop their game. Over the course of the three presentations, it was clear that students were evolving to follow best-practice and that the quality of the presentations increased dramatically as students came to realise its importance. Professional market research and very polished advertising videos featured prominently in many of the final presentations. All four of the games that were developed further paid enormous detail to the execution of their presentations.

We believe that the success of the four games that the external stake holders requested be developed further was directly related to how much those teams adapted of the core entrepreneurial skills.

5 Conclusions

Teaching entrepreneurial skills to students is very difficult in a classroom. With this in mind, colleges across the EU and globally have tried to adapt various measures to make entrepreneurship teaching more focused and 'real-life'. As with all learning, deep learning is only achieved when students fully engage with the subject that is being taught. Students need to 'do' to really understand. We believe that the approach taken in the WalkAbout projects is an excellent method for teaching entrepreneurial skills in a very real, hands-on, environment.

The WalkAbout projects forces students to realise that a successful business is more than just a piece of code or a storyboard or a business plan. WalkAbout projects take students outside of their comfort zone by presenting them with a cross-disciplinary project. This coupled with the international aspect of the project forces students to engage with the skills that are required to be a successful entrepreneur.

Students who took part in the WalkAbout projects were not given any formal lessons in the subject of entrepreneurship while on the project. Instead, they utilized and evolved their own skills during the life-cycle of the project. Future incarnations of the project may include some formal classes on the subject of entrepreneurship, as we is now believed that this could result in even more polished results

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Exploring the ICT Proficiency Level among Primary and Secondary School Teachers in Lao PDR

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Abstract. This study marks an important contribution to the education section in Lao PDR concerning teacher's ICT proficiency, which aims to reflect the outcome of student teachers in each of the teacher training programs. The study is focused on how teachers perceived basic ICT application knowledge and skills. A survey was completed by 200 teachers who teach in primary and secondary schools from eight districts of Salavan province. The results show that both primary and secondary school teachers perception of basic ICT applications is different, Also that male teachers' proficiency in using ICT is higher than female teachers. In addition, how Teacher Education Institutions organize and encourage student teachers to be accomplished in promoting teaching and learning with ICT is discussed.

Keywords: exploring the proficiency in using ICT, teacher education in Lao PDR, ICT competency, ICT integration, in-service teacher, teaching and learning with ICT, Salavan TTC.

1 Introduction

Information and communication technologies (ICT) are dynamic influences in a changing society. They are increasingly influencing all aspects of life as well as at the school level. Over the last decade, more than 700 empirical research studies on the impact and effectiveness of technological education has shown that student achievements are positive [20]. ICT exists as tools which enhance and are able to solve numerous varieties of teaching and learning activities. At present, the majority of educational institutions have ICT applications in their curricula. For example, UNESCO has defined the usefulness of ICT as it can contribute to universal access to education, equity in education and the delivery of quality learning and teaching [25]. They have been running many projects with the goals to integrate ICT into teaching and learning activities, and the results of these projects show that ICT has positive effects. In 2011 more than 90% of students in primary, lower secondary and high schools in Asian countries has been instructed in basic computer skills [27]. The role of ICT in education is effective in the delivery of quality education and is becoming increasingly consolidated. Teachers and students are faced directly with the growing and expanding digital technologies, both in society and at the school level. We have become familiar with the teaching and learning skills required for the 21st century. For example, the Partnership for 21st Century Learning (P21) has developed a framework for the skills of the learner in this century. The implementation requires the development of key academic subject knowledge and understanding among all students who must learn the essential skills for success in today's world, such as critical think, problem solving, communication and collaboration [16]. The P21's vision and mission emphasizes the skills, knowledge, values and attitudes that learning and teaching promote must reflect and respond to the needs and expectations of individuals, society, countries and the world of work today.

Teachers are the key to improving the quality of learning, they have a powerful impact on upgrading the quality of student learning experiences [26]. Teachers are faced with many challenges in integrating ICT into their teaching and learning activities. This means that the teachers' ICT literacy is critical in enabling teachers to incorporate ICT into their teaching activities. Recently many researchers have studied strategies to assist teachers to accomplish teaching and learning with ICT. Mishra and team (Mishra, 2006) insist that effective teaching is contingent upon teachers' abilities to represent and formulate the subject matter so that it is comprehensible and accessible to students. The heart of good teaching with technology has three core components, technology, pedagogy and content knowledge. On the other hand, UNESCO has been working for many years to improve and develop the quality of education by supporting and promoting teacher use of ICT for teaching and learning around the world. They believed that using ICT in education has been widely accepted, and the potential of ICT brings positive impacts to teaching and learning by providing students and teachers with flexibility, accessibility and more opportunities of participation and collaboration [24].

In Lao PDR, the government has had a recognized ICT policy in education since 1998. However, the expansion ICT in schools has been limited. Most of the ICT funding in schools and colleges was used to facilitate ICT for the educational administration. In 2011, the Ministry of Education and Sports (MoES) introduced a new ICT policy called "ICT4 Education". The goals of the new policy was to build the ICT educational infrastructure, promote ICT integration in the classroom, improve education administration and teachers' ICT knowledge and skills. The project includes eighteen ICT centers in the country with one built in every province and this work was completed in 2013. Each center consists of computer rooms, network management rooms, lecture rooms, distance learning rooms and science laboratories. Some high schools in each province have installed a computer room in which to provide the teaching and learning of ICT [14]. Concurrently, many secondary schools and Teacher Training Institutions have installed personal computers and ICT equipment [28]. All teacher training programs have integrated ICT into the curriculum, most student teachers have access to ICT facilities for learning, study and skill development purposes. However, there are around 70% of teachers in local primary schools who want to learn or improve their professional knowledge and ICT skills for teaching and learning in the classroom [11]. The current situation of teachers in all regions of Lao PDR is that only some schools and teachers have access to ICT tools and do not have the skills to implement the MoES's policy for using new technological applications. The Teacher Training Colleges (TTCs) have the responsibility for ensuring the quality of both pre-service and in-service teachers so they have to explore into what pre-service or in-service teachers' needs are, and how to help or support them to improve and develop their knowledge and skills. According to the 2017 academic year report from the Salavan Province Education and Sports Service (PESS) there is one ICT center which helps to support the use of ICT for education in the province. For the past 5 years some teachers from primary and secondary schools have been trained in the use of ICT applications as well as basic computer and internet skills. However, many teachers still do not usually use ICT [18]. It is not clear which skills and knowledge these teachers do not have but need. Therefore, this study aims to explore what the secondary and primary school teachers' perception of ICT is. The results from this study will be conveyed directly to the TTCs in order to ensure the quality of outcomes for pre-service teachers for each course or program. The study is focused on the content of the basic knowledge and skills for the use of ICT, as well as what teachers' current knowledge or ability is in the use of computer programs such as Microsoft Office and of the use of the internet.

2 Literature review

In 2013 the Ministry of Education and Sports (MoES) implemented a new ICT policy for education. The aim of the policy is to build the ICT infrastructure for education, enhancing the quality of high school education, improving and developing the education information management systems and upgrading the human resource for using ICT in education [13]. The academic year report (2015) of the ICT Center for Education and Sports states that eighteen ICT centers had have built and were completed in 2013. Each ICT center consists of computer rooms, network management rooms, lecture rooms, distance learning rooms and science laboratories. This project aims to build the infrastructure for using ICT in education. Three projects have been carried out; the creation and development of web-based learning, a forum for promoting the learning resources online, and experimentation of teaching and learning by using video conference work with Lao teachers and students. The broadcast of teaching is form a high school in Vientiane and live to two high school in Luang Prabang and Champasack [14].

The ICT infrastructure started many years ago before the new ICT policy was implemented, but it did not expand very widely. Many secondary schools and Teacher Training Institutions had installed some personal computers and ICT equipment. For example, 122 personal computers were piloted in sixteen secondary schools which was supported in different provinces by projects such as Smart School (2001-2005) and ASEAN School Net (2003-2006). Additionally, 294 personal computers were installed in five Teacher Training Colleges (TTC) and three Teacher Training Schools (TTS). Most piloted secondary school and TTCs/TTSs have a Local Area Network connection (LAN) and internet access. The personal computers, LCD projectors and LAN/Internet are used for teaching and learning in the ICT lab [28].

The Teacher Education Institutions (TEIs) started using ICT for teaching in 1997. The majority of teachers who work in TEIs have learnt using ICT for teaching through training workshops incorporating tape recordings, video, overhead projectors and video cameras. Teachers use ICT as a teaching tool as well, not for student learning. Formally many teachers could not use ICT equipment especially computers, only mathematics and science teachers had the opportunity to use computers and integrate them into their teaching. To build the capacity of TEIs to prepare the next generation of teacher for ICT and to enhance the quality of teaching and learning from 2001-2006, the Department of Teacher Education (DTE) organized numerous workshops on the use of computer for teaching and learning which was supported by the Project Improving Science and Mathematics Teacher Training (SMATT).

In order to pursue the improved quality of teachers in TEIs, the Department of Teacher Education (DTE) and UNESCO signed an agreement to established a three year plan (2006-2008) for the promotion of the use of ICT applications for TEIs particularly in Luangphabang TTC, Bankeun TTC and Savannakhet TTC. Many schools, institutions and universities have played a role in ICT development mainly for classroom teaching. These teachers are very active and effective in the use of ICT [28]. The development and use of ICT in education in Lao PDR has been increased rapidly since 2009. Both public and private schools have installed ICT tools to promote the quality of teaching and learning additionally many private schools have organized smart classroom [14]. The five year plan of ICT center for Education and Sports will continue to expand and to contribute computers and ICT tools into lower secondary, and primary schools [14]. MoES also proposed that 565 computer rooms will be supported for teachers in the 145 districts of Lao PDR, and at the same time principals and teachers will be trained to use those tools and applications [15].

The development of ICT in education abroad has been practiced for many years, all developed countries have promoted teacher training with ICT, they have studied various strategies for teaching and learning with ICT or how to integrate ICT into the classroom. For example, Seymour Papert (1960), [17] studied about providing computers as an instrument for learning, and enhancing creative computational thinking. At that time, many people derided him when he expounded his theories. However, he was the first to show the impact of new technologies on learning in general, his research results showed that children who has had the chance to use computers to write and to make graphics to represent geometrical and mathematics concepts had progressed rapidly in their knowledge and understanding. He is now considered the world's foremost expert on how technology can provide new ways to learn and teach mathematics, thinking in general and other disciplines [21].

In the US, from 1963 to 1985 the education sector tried and supported new technology in the classroom. At this time IBM was the first mainframe computer manufacturer to develop a PC, concurrently Apple developed the Apple Macintosh computer including computer-based tutorial and learning games. There, 25 percent of k8 and high school used PCs. Many schools used videodisc and object-oriented multimedia authoring tools, simulations, educational databases and other kinds of Computer Assisted Instruction (CAI) programs which were delivered on CD-ROM disks. The use of disks helped students to save their work and data [31].

From 1993 to 1997 the internet expanded rapidly and became the world's largest database. Access to information, graphics and video streaming made it an invaluable resource for education. Accordingly Stanford Research Institute (SRI) investigated the preparation of teachers to integrate technology into the classroom. From 1995-2000 it was found that the Multimedia Project (MMP) was a powerful way to transform teaching and learning with technology, particularly in the teacher professional development program. The new teachers have developed skills both in pedagogy and instructional uses of technology [4]. Technological development, and of the introduction of the new technologies into education accelerated dramatically during the year 1990, including the combination of computation, connectivity, visual and multimedia capacities and has radically changed the potential for technologies in the school room [9].

Now the roles of ICT in education enhances the quality of teaching and learning as well as improving the learners' skills for the 21st century. These challenges are faced directly by the teacher who will organize the teaching and learning activities with the new technology applications. In recent years several researchers have attempted to develop and find out the best ways to improve and develop the teachers' ICT proficiency or teachers' ICT competency so that they will be able to integrate it into the classroom. In addition, many frameworks have appeared such as ICT-CFT (ICT framework for teacher), and TPACK (Technological Pedagogical Content Knowledge). The ICT-CFT was proposed by UNESCO (2011) and focused on improving teachers' competency in the use of ICT integration into classrooms [23]. The TPACK framework was developed by Koehler and Mishra (2006), the purpose of this framework was to encourage teachers to integrate ICT for teaching and learning. It had significant implications for teachers and teacher educators [12]. If teachers perceived in seven sub domains in TPACK, it determines that teachers are enable to integrate ICT into their teaching and learning [2].

ICTs are seen as important tools to enable and support the move from traditional teacher-centric style to more learner-centric methods [8]. The majority of teachers want to learn how to integrate ICT in the classroom effectively and efficiently [1]. Not only mastering ICT skills, but also utilizing ICT to improve teaching and learning is of great importance for teachers in performing their role as creators of effective pedagogical environments [10]. Many countries have attempted to find out ways to motivate teacher to use ICT in the classroom in the context of new curricula and pedagogies [29].

3 Research objective and research question

This study aims to explore what the secondary and primary school teachers' perception is of the knowledge and skills used in ICT, such as the basics of using some applications of ICT including; working with the folders and files, word processing, spread sheets, power point, and the internet. In-service teachers learnt this when they studied at the TTCs or they learnt independently. Previous studies about in-service teachers' knowledge and skills of using ICT indicated how teachers needed to improve their professional knowledge and skills but it did not represent what teachers know or their ability to use the basic ICT applications. Thus, this study has focused on what skills and knowledge the teachers have. So, the research question is;

What do teachers know of these five core skills; working with the folders and files, word processing, spread sheets, power point, and the internet?

4 Methodology

The research design for this study is based on the survey research for collecting data and describes the specific aspect of population or a portion of the population [19]. The survey was conducted to collect data, mostly quantitative, on teachers' ICT proficiency. The questionnaire was adopted from the Department of Education and Training, Western Australia which they produced by reference to the Department's teaching and learning with ICT, and other 100 schools Professional Learning Program Evaluation. It was reviewed through teachers' application of ICT [6]. It is a self-administered questionnaire which consists of two sections. Section 1 is on the demographic information of the respondents, and section 2 consists of five questions with 36 items. All items in the five questions were measured in the five-point Likert scales. It has been translated from English into Lao, and then taken to the academic council at the Salavan Teacher Training College for identifying and qualifying its context. Then utilized for a pilot test with a small group of primary school teachers, with minor amendments to the survey form to ensure comprehension and completeness. The questionnaires were distributed to 200 primary and secondary school teachers in 32 schools in eight districts of Salavan; Wapi: 37; Salavan Capital: 28; Lakhonpheng: 28; Samoi: 23; Laognam: 21; Khongsedone: 21; Taoy: 21; and Toumlan: 21 teachers. In order to interpret the information, descriptive statistics were used to find the Mean scores, Average of the Mean and Standard deviation by using the functions of the formula on the Microsoft Excel. Each of the five core skills were assessed on the questionnaire using a five point scale where 5 (Strongly agree) represents the maximum score and the 1 (Strongly disagree) represents as the minimum score.

5 Finding

5.1 The demographic of respondents

Table 1. Sample profile of the survey

Item	Demographic	Frequency	Percentage (%)
Gender	Male	81	40.5
	Female	119	59.5
Age	21 - 24	17	8.5
	25 - 29	75	37.5
	30 - 35	58	29
	35 up	50	25
Teacher training programs	Primary school	104	52
	Secondary school	96	48

The data from Table 1 shows that the number of female respondents (n = 119) 59.5%, is higher than males (n = 81) 40.5%. The age of the respondents was, 21-24 (8.5%) and then 25-29 (37.5%) while 30-29 (29%) and more than 30 years old is 25%. The number of respondents who were primary school teachers (n = 104) covered 52%, and secondary school teachers (n = 96) equal 48%.

5.2 Teachers' perception of each content

Table 2. Teachers' perceived contribution by gender

Item	Males		Females	
	Mean	SD	Mean	SD
Working with folders and files	2.71	1.62	1.90	1.24
Word processing	2.68	1.54	2.01	1.31
Spread sheet	2.38	1.5	1.83	1.6
Presentation	2.19	1.38	1.74	1.08
Internet	2.08	1.45	1.78	1.19

Table 2 shows that the Mean and SD of males and females is quite different as the males (Mean is between 2.08 – 2.71, and SD between 1.38– 1.62). The females (Mean between 1.74 – 2.01, and SD between 1.08 – 1.24). It represents that most of male teachers have the average of Mean near the middle compared to top score, however, female teachers are well below the middle.

Table 3. Teachers' perceived contribution by age

Item	21 - 24		25 - 29		30 - 35		35 Up	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Working with folders and files	2.24	1.47	2.55	1.48	2.37	1.43	1.77	1.42
Word processing	2.31	1.53	2.6	1.43	2.23	1.44	1.86	1.35
Spread sheet	2.13	1.3	2.26	1.36	2.03	1.40	1.74	1.28
Presentation	2.11	1.34	2.00	1.23	1.98	1.27	1.48	1.01
Internet	2.15	1.40	2.28	1.44	1.89	1.23	1.44	1.01

The data from Table 3 shows that the Mean and SD of teachers who are aged from 25-30 is highest (Mean is between 2.00 – 2.55, and SD between 1.23– 1.48), followed by teachers aged 21-24 (Mean between 2.11 – 2.24, and SD between 1.30 – 1.47), and teachers who aged 30-35 are similarly in the second place (Mean between 1.89 – 2.37, and SD between 1.23 – 1.44), and the lowest is teachers who aged at 35 or above (Mean between 1.44 – 1.86, and SD between 1.42 – 1.42)

Table 4. Teachers' perceived contribution by teacher training programs

Item	Primary school teachers		Secondary school teachers	
	Mean	SD	Mean	SD
Working with folders and files	1.34	0.78	2.54	1.44
Word processing	1.38	0.84	2.56	1.44
Spread sheet	1.29	0.69	2.32	1.34
Presentation	1.27	0.66	2.13	1.26
Internet	1.28	0.90	2.15	1.37

Table 4 indicates that the Mean and SD of teachers who graduated from primary school teacher programs is very low (Mean is between 1.27 – 1.38, and SD between 0.66 – 0.9). The teachers who graduated from secondary school teacher programs is higher (Mean between 2.13 – 2.56, and SD between 1.26 – 1.44). This indicates that the majority of teachers who graduated from secondary school teacher programs are more familiar with using ICT than teachers who graduated from primary school teacher programs.

6 Discussion

According to the results from Tables 1 - 4, the average of the Mean scores of each content in five parts of the questionnaire including working with the folders and files, word processing, spread sheet, power point, and the internet is highest at the middle level. Male teacher scores are higher than female teachers, the group of teachers aged between 25 – 35 is the highest, and most teachers who graduated from secondary school teacher programs is higher than those teachers who graduated from primary school programs. These results suggest that most in-service teachers perceptions of basic knowledge and skills of using ICT is low compare to the 5-point scores. It shows that there are many teachers who do not know how to use computers, and the new technological applications. So, what happens? Even though they had have learnt to use ICT when they were student teachers, and now have easy access to the new technology their scores are still low. Referring to the results of the data from Table 1-4, it is considered that the reasons why most teachers still lack professional knowledge and skills in the use of ICT in the classroom is related to the curriculum and teaching practice of teachers in the Teacher Education Institutions (TEIs). The core curriculum of both the primary schools and secondary school programs are similar, it has placed the ICT contents, particularly using a computer into two subjects; Compute 1 and 2. Each of these subjects is taught for 32 hours. Many TEIs are still unable to fully facilitate and promote student teachers access to ICT. This corresponds to the results of the investigation from the Basic Education Quality and Access in Lao PDR or BEQUAL which represents that there are many teachers in the TEIs that cannot use ICT applications for teaching and learning. This has affected the student teachers' ability to use ICT too [3]. This situation is the basic issue which can be found in all regions of the world. For example, Gulbahar et al. (2008) surveying on the use of ICT tools in primary school for the social studies subject area in Turkey found that where teachers are willing to use ICT and are aware of the existing potential, they are still facing problem in relation to access to ICT resources and there is lack of in-service training opportunities [7]. And it similar with the results from the surveying use of ICT in education for schools in Europe represented that most teachers and students have been familiar with ICT at the classroom but only a few use it [30]. If we consider the gender, age and majors of student teachers are not influences on the teachers' perception of ICT as referred to the Teo (2008) who studied about pre-service teachers' attitude toward computer use in Singapore. He suggested that the greater level of computer experience is associated with more positive computer attitudes, however, male and female had rated themselves on their ability to use computer in significantly different ways, and female usually had a more negative attitude to computer use. He also found that student teacher who majored in different subject domains had significantly different perceptions [22].

7 Conclusion and recommendation

The findings of this study indicate that the number of teacher who lack both knowledge and skills in using ICT is still high. This situation indicates that the government or education sector has to seriously consider greater support for supplying both hardware and software into schools. Also, TTCs should consider reform and adoption of new ICT content into the curriculum to ensure the quality of pre-service teachers which will fulfill the three core subjects as well as technology, pedagogy, and content knowledge. These results also indicate that the Teacher Education Institutions should consider changes in the learning and practice of ICT to encourage a more relaxed learning environment so students can be better prepared for the digital era. In addition we have seen that most countries around the world are intent on improving and developing the quality of teaching and learning by promoting and supporting teachers integrating the technology into their teaching and learning. However, teaching and learning with technology is quite onerous for the teacher and student as researchers have mentioned that technology is a tool which empowers and enhances the quality of education. Without technology the quality of education will decline. Thus, teachers must have the ability to integrate ICT into their teaching and learning.

The information communication and technology (ICT) has a role to enhance the quality of education. We have seen that the development of technology for education has a long history and is still progressing. At present many educational organizations are attempting to adapt and integrate ICT. These factors are a great challenge for both students and teachers in this digital era. There are plenty of technology applications and teaching and learning tools which teachers and students can use as learning resources and for skills practice. For example, many people are learning by watching video streaming on the YouTube, Facebook and other similar mediums. The result is that the learning space is unlimited, we can learn when we want and we can learn what we want. So, it is very important for the teachers and students to have access to the big data sources for lifelong learning.

The results of this study are related for both the pre-service and in-service teachers' professional knowledge and skills in integrating ICT. Reform of the educational administrations, teachers, and student teachers have to rethink about the potential of teaching and learning with ICT both in the TTCs or local schools. Therefore, this study has shown that there are a number of strategies that developed and developing countries have used successfully in their approach to the adoption and inclusion into their teacher education programs. Some countries have reformed their education system as defined the ICT policy or ICT master plan, with three or four phases. And many education institutions have determined additional strategies in their approach to ICT in education. For example, there are several studies about how to promote ICT use for both pre-service or in-service teachers in difference conditions. However, in order to solve these problems which were encountered in this study, it could be possible to endeavor to launch some theoretical ICT as well as the introduction of technological pedagogical content knowledge or TPACK framework [12]. It emphasizes teachers understanding of integrating ICT. Most researchers are insistent that the heart of good teaching with technology has three core components; technology, pedagogy and content knowledge. TPACK framework has been examined in several subject areas, and it has proved effective in enhancing the pre-service and in-service teachers to assist them in improving and developing their professional knowledge and skills. In addition, in order to improving the pre-service teachers' ICT knowledge and skills, TTCs teachers must integrate ICT exemplarily in their teaching and work with learning management systems confidently and bring their newly acquired knowledge into their classroom, and at the same time they will automatically teach their colleagues [5]

For a future study I would like to suggest, research into how to enable pre-service teachers to use and approach new technology innovatively for their learning and teaching practice. This can fulfill their knowledge and skills in integrating ICT into their coursework as well as being based on technological, pedagogical, and content knowledge or TPACK framework.

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ICT Using in Integrated Teaching Management Core Courses in a Foreign Language

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Abstract. The paper deals with the practical importance of using ICT in education which is difficult to overestimate. The research studies the process of integrated teaching management core courses in English using ICT with the purpose of developing the technology of integrated building of professional and foreign language competences using ICT. The authors analyze the ways of the effective ICT use in the integrated teaching the courses "Corporate Social Responsibility" (in English) and "English for professional purposes" and statistically prove their effectiveness.

The developed integrated model using ICT has proved the synergy effect allowing the effective acquisition of professional information on the one hand and the development of both professional and foreign language skills on the other hand, what ensures building the professional competence as a whole. The results of the experiment can be used in developing of the recommendations as to using ICT in the integrated teaching of core courses and foreign language to future managers.

Keywords: Information and Communication Technology, Integrated Learning, Integrated Teaching Model, Professional Competence, Foreign Language Communicative Competence.

1 Introduction

The tendency of scholars raising interest in the problem of implementation of Information and Communication Technology (ICT) in education process is observed in Ukraine under the development of information society and the modernization of the system of higher education. The solution to this problem is the system of integrated teaching of core courses and a foreign language using ICT at the lessons and for independent work.

The requirements of the modern education to build the multiple personality demands the rationalization of the process of both professional and language teaching future managers on the basis of innovative efficient educational technologies stipulated by the contemporary requirements and real conditions of the higher school.

The authors of modern researches have investigated different aspects of the problem of ICT implementation in education. Communicative and speech characteristics of informational media of communication were studied by V. Dronov [1], M. Yevdokimova [2], S. Zenkina [3], T. Koval [4], O. Pankratova [5], I. Rozina [6], H. Selevko [7], T. Lawrence [8], P. Wallece [9], M. Warschauer[10] and others. The didactic characteristics of ICT have been considered by T. Mooij [11], E. Polat [12], M. Biechele [13], and others. The problems of adult learners and technology based learning have been touched upon in the works of L. J. Ausburn [14], S. K. Bajt [15], M. Johnson [16], and others. J. Lo Bianko [17] considered different aspects of using ICT in literacy learning and case studies have been considered. The Ukrainian researchers Yu. Bryta [18], Ya. Dyachkova [18], N. Mayer [18], Ya. Krapchatova [18], V. Chernysh [18] have studied the perspectives of ICT using for building the foreign language communicative competence in different types of speech activity.

Equally important it is to consider the negative factors accompanying integrated teaching using ICT. B. El Mansour and D. M. Mupinga [19] note rigid schedule (as opposed to the on-line courses) and technical problems among the most frequently mentioned by students. J. Nworie and N. Haughton [20] consider the list of unanticipated effects including “technology-supported cheating opportunities; communications-related distractions from emails, instant messaging, computer games, web surfing, and other "personal projects;" lack of engagement with the instructional setting caused by the substitution of classroom experiences with pre-recorded and downloadable class materials from various sources”. E. Zhu, M. Kaplan [21] P. Demian, J. Morrice [22] touch upon the negative influence of ICT on teaching process.

The analysis of the researches conducted in this field, the regulations and teaching materials, as well as observations of the teaching process in the higher school have allowed to define a number or contradictions:

- between the requirements of the society to the quality of professional education in management, the needs of higher educational institutions in scientifically and methodologically grounded materials for the efficient educational process using ICT on the one hand and the lack of the developed materials for teaching core courses and foreign language on the other hand;
- between the new requirements of educational programs to build competences within the amount of ECTS and few classroom hours for every.

The topicality of our research is grounded on the urgency of resolving the above mentioned contradictions and the need in investigations dedicated to the implementation of ICT based integrated learning into the management degree program.

The practical importance of using ICT in education is providing autonomy, mobilizing of learning abilities of students, creating conditions for individual learning and developing of active position in learning activity. Using ICT in teaching subjects in English opens new methodological perspectives of developing degree and subject programs for future managers.

The object of the study is the process of integrated teaching professional subjects in English using ICT to future managers. The subject of the study is the technology of integrated building of professional and foreign language communicative competences using ICT.

The aim is the analysis of the effective ICT use in the integrated teaching the courses “Corporate Social Responsibility” (in English) and “English for professional purposes”.

The following theoretical and empiric methods have been used in the research: critical analysis of resources, current programs, education regulations, manuals; method of observation, questioning of students and professors to reveal their attitude to different aspects of ICT using in higher school; simulation method to develop the education model within the standard amount of ECTS credits; education experiment and statistical processing of data, obtained in the experiment to check the effectiveness of ICT using in education.

2 Organization of Educational Environment Using ICT

The development of the education process at higher school in the information society is connected with using of virtual environment [18]. According to M. Nimatulayev [23] the advantage of education organization using ICT environment is the opportunity to perform the approach based on individual activity, namely creating the conditions for self-learning and personalization of the learning process of every student. I. Rozina [6] states that learning using ICT environment is the brand new paradigm based on the functional effectiveness of ICT and built on the e-learning culture comprising the positions of an e-learner and an e-teacher

Following the opinion of S. Zenkina [3] we consider the ICT environment as a complex of electronic methods of teaching and communicating using of which allows performing the gradual learning activity that builds both professional and foreign language competences of a student. V. Dronov [1] believes that the modern ICT environment is to meet the requirements of students, to be able to adapt to different educational situations and to possess the corresponding content and structure. That is why we have generalized the experience and implemented the following modern information and communication technologies:

- Information education technologies (search engines, educational Internet portals and services Web 2.0, education webinars, electronic manuals, computer educational programs, audiovisual and multimedia materials, etc);
- The Internet oriented teaching technologies (education programs, presented in the Internet, on-line tests, on-line courses, LMS Moodle);
- Activity oriented technologies (projects, group work facilitation, professional business game, problem solving, etc);
- Case technology based on using the cases in audiovisual and multimedia sources in independent study;
- The foreign language integrated learning technology (creation of content and information interdisciplinary connections to build the foreign language competence, the technology of integrated building of professional and language competences, etc).

Special attention in the process of organization of independent learning should be paid to web technology / the Internet technology, especially different communication opportunities such as

- synchronous communication - Internet Relay Chat (IRC), ICQ, Skype, Viber;
- asynchronous communication – email, messaging;
- multimedia technologies – communication using visual, sound and video files.

The effective education process presupposed the organization of the control provided by teachers and the opportunity for students to get regular consultations, to exchange information, to communicate and to jointly perform different projects.

The Internet social services have proved their expediency as they have completely changed the education process by its personalization and practice orientation. The scholars determine the following important for education purposes characteristics of the Internet services as personalization, cooperation of users, web interaction, information accumulation and content modification [18]. The following services can be implemented in education process: Blog, Social networking, Wiki, Bookmarks, Webquest, Podcast, Twitter, Skype, Google Docs, Google Maps, You Tube, Conversational arenas, etc.

The system of distance learning is supported by different LMSs. ATutor, Dokeos, ILIAS, Moodle are among the most effective since they provide the open access to their services [18]. There are some other platforms that are widely used: Acollab, Claroline, Colloquia, Ganesha, LAMS, Sakai. LMSs allow students self-control, individual communication, combination of traditional and computer learning tools. In general they positively affect building professional foreign language competence in the process of independent work.

3 The Proposed Model of Integrated Learning Using ICT

The proposed model of integrated teaching professional courses in English using ICT was created on the basis of major course "Corporate Social Responsibility" (taught in English) and the course "English for professional purposes" for the second year students of specialty 073 "Management" of Zaporizhzhya National University considering the following amount of credits and classroom hours: the course Corporate Social Responsibility – total hours 150 (5 ECTS credits), classroom hours – 48, the course English for Professional Purposes – total hours 90 (3 ECTS credits), classroom hours – 32.

While developing the model the authors came to the conclusion that two variants (A and B) can be implemented depending on different ICT used in integrated teaching the professional courses and the foreign language.

The courses in our experiment are part of the curriculum of bachelor degree program in management. The main goal of the experiment was to determine the level of influence of ICT on the quality of learning.

Variability of the experiment is presented through two variants: A and B models of integrated teaching using ICT. Invariables of the experiment are the groups (EG1, EG2, EG3, EG4) composition: number of participants (13 students in each group) and their knowledge level; program content and study material; the control content before and after the experiment; time and duration of the experimental learning; criteria of checking of professional and foreign language competences in all groups; teachers in each group.

Our investigation was held in the third semester of two consecutive academic years (2016-2017, 2017-2018). The total amount of students, that took part in the experiment – 52 students. The questionnaire that was held among the students revealed some of the strongest stimuli (from the students' point of view) for the development and implementation of ICT into the learning process. Having prioritized these stimuli we obtained the following list:

1. Building of professional independence.
2. Wider opportunities to successfully finish the course.
3. Development of competitiveness.
4. Academic mobility.
5. Knowledge acquisition.
6. Adaptation of new forms of activity.
7. Changing of communication mode between the subjects of the process.

Table 1. A and B variant of the integrated teaching model using ICT.

Course	Information communication technologies									
	Information education resources	Electronic manuals	Podcasts, multimedia resources	On-line control tasks	Special on-line courses, webinars	On-line consultations, chats, Viber	Project technology, web-quests	Case technology	Facilitation, professionally oriented business games	LMS Moodle
Variant A										
Corporate Social Responsibility (in English)	+	+	+	+	+	+	+	+	+	+
English for professional purposes	+		+	+		+	+	+	+	+
Variant B										
Corporate Social Responsibility (in English)	+		+	+				+	+	+
English for professional purposes	+		+	+				+	+	+

The learning management system (LMS) Moodle has been used as the platform for implementing the ICT into the courses programs. The choice of LMS is predetermined by the following opportunities that are of paramount importance for our research: joint activity of all subjects of the learning process; development of different types of control tasks; design of different types of tasks; using different languages; holding on-line seminars; organization of the forum and others.

The programs of the courses “Corporate Social Responsibility” and “English for professional purposes” have been developed within the same structural chart providing the opportunity to integrate two courses into one system. Such structure gives the opportunity to educators to regulate the learning process in defining the goal, planning, performing, evaluating, and correcting. The design of the courses programs presupposes the following main sections each including the ICT:

- Section 1 – introduction and preliminary acquaintance with the subject;
- Section 2 – theoretical knowledge and practical tasks to facilitate learning process;
- Section 3 – knowledge control;
- Section 4 – referral system.

Section 1 - introduction and preliminary acquaintance with the subject. The tasks to be solved within this section are the following: to motivate the students to take the course, to awake their interest in the content of the subject as well as the form of its presentation; to get student ready for the independent use of multimedia manuals and the Internet resources. The main elements of this block are the course presentation and the course program. The courses presentations include information education and multimedia resources.

Section 2 – theoretical knowledge and practical tasks to facilitate learning process. The tasks to be solved within this section are the following: the opportunity to change the content of the course, the form and order of its presentation depending on the level of students’ knowledge, their personal and psychological peculiarities of acquiring information; the provision of effective personalized dialogue among all participants of learning process.

The main element of this section is electronic manual. We have already developed and put into use the electronic manual for the course “Corporate Social Responsibility”. The main characteristics of this manual are the following: didactic fullness of the presented content; division into topics, material presentation compactness; multimedia applications, interactive fragments; practical tasks on every topic; questions (tests) for self-control on every topic; questions (tests) for final control or self-control; referral system, prompts; opportunity to use the manual off-line. The electronic manual for “English for professional purposes” is being developed. For the purpose of the experiment we used the texts on the topics relevant to the course “Corporate Social Responsibility” (e.g. stakeholders’ analysis, social capital, sustainability, etc.) and defined the language material to develop the foreign language competence. Certain exercises and tasks based on this language material are presented in Moodle. The course program stipulates the study of the case on Corporate Social Responsibility (a team project for independent work that is to be presented in the form of PPT presentation with the elements of discussion encouragement through the use of different facilitation techniques). As part of their individual work the students are supposed to register for an on-line relevant course in English.

The next element of the section is lectures for the course “Corporate Social Responsibility”. Since we use the integrated learning system the content of the lectures is presented in Ukrainian and English in the form of PPT presentations. The lecture notes allow students to preliminary get acquainted with the problem to be discussed at the lecture as well as to obtain the knowledge necessary to occupy the proactive position and to hold the efficient dialogue at the lecture. It is worth to note that presenting the lecture notes in English pursues several goals. It promotes building the skill of using the English language as an instrument of information search; gets the students with different level of English ready to listen to the lectures in the English language; promotes building communicative competence of students.

Bilingualism in lecture notes receives its logical development during seminars and round tables. All the seminars tasks are of search character. Students are offered to find the solutions for practical tasks, to study the experience of different companies, to analyze the corporate reports on sustainability and social responsibility, presented on the websites of companies. The English language segment of the Internet opens wider opportunities in terms of obtaining information, especially in such novel for Ukraine field as Corporate Social Responsibility.

Section 3 – knowledge control. The tasks to be solved within this section are the following: to reveal knowledge initial level; to detect individual abilities of knowledge acquisition; to individualize the learning and control processes, what inevitable increases the quality; to efficiently manage the learning process.

The following bar charts demonstrate mean success indicators (blue bars – before the experiment, red bars – after the experiment) in all groups participating in the experiment presented as the percentage of the fulfilled tasks.

The main difference of the knowledge control procedure using ICT is the opportunity of the well-timed development of the necessary measures of correcting the learning process to increase its quality. The following are the advantages of the knowledge control using ICT:

1. The main characteristic is making more time available for the teacher. This time can be spent on individual work with students, the definition of a particular approach to every student based on the fulfilled tasks (a placement test “English for professional purposes” or an essay “Corporate social responsibility”).
2. The students survey revealed the priority characteristic of the control using ICT being the elimination of the subjective factors and the creation of equal conditions for all participants of the process.
3. Both professors and students noted the increase of individualization in learning process. Students have the opportunity to choose the most suitable method of knowledge acquisition and the most convenient way of control tasks fulfilment. They can repeat the study and control procedures several times if necessary what promotes the development of the individual work skills.
4. The student is able to obtain the prompt information about the knowledge acquisition results fulfilling self-check tasks. This characteristic is very important both for professors and students providing the opportunity to timely correct the learning process and obtain the necessary results.

5. One of the most important advantages is the improvement of psychological situation due to availability of information from different sources during learning and control processes, the opportunity to fulfil the tasks in convenient time and comfortable settings, the fulfilment of team projects.

The main element of the control is testing. It is worth mentioning that the traditional control procedure can provide only the statement “passed - failed”, while the procedure of the computer testing presupposes additional acquisition of the content due to provision of several attempts and the system of prompts included in every test.

Section 4 – referral system. The tasks to be solved within this section are the following: facilitation of the content acquisition; increase of interest in the subject; building students’ information culture; opportunity to join the world information community.

This section comprises the glossary, the list of recommended literature, the list of the websites providing on-line courses and the list of useful Internet sources. The glossary includes the main terms to facilitate the acquisition of the content. The main criteria for including the source into the recommended list is professionalism and simplicity in rendering information, building search and research skills, development of the interest in the subject. One more element of the referral system is the navigation system developed in the electronic manual.

4 The Verification of the Effectiveness of Using ICT in Education

The analysis of the results of control before the experiment showed that the level of professional and foreign language competences was inadequate (EG1 – 67,9%, EG2 – 67,7%, EG3 – 68,1%, EG4 – 67,0%). The results of the control after the experiment proved that the students of all four groups achieved and excelled the minimum enough level of competences (EG1 – 90,3%, EG2 – 89,9%, EG3 – 88,2%, EG4 – 87,6%).

The following bar charts demonstrate mean success indicators in all groups participating in the experiment presented as the percentage of the fulfilled tasks.

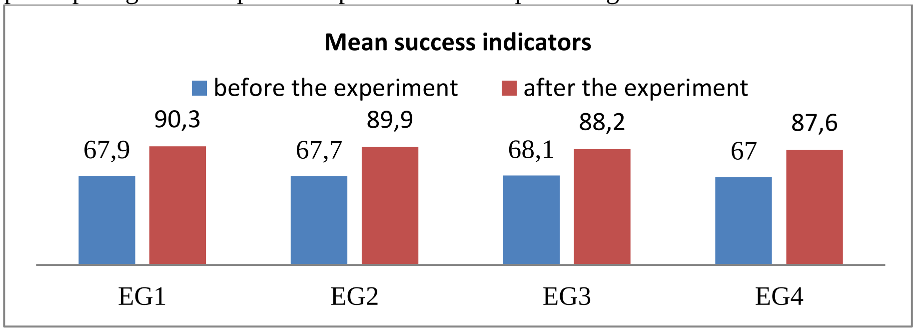

Fig. 1. Professional foreign language communicative competence before and after the experiment.

Integrated teaching core course "Corporate Social Responsibility" in English using ICT caused higher level of competence in all experimental groups, what proved the general effectiveness of the proposed model. Though the competence level coefficients are higher in EG1 and EG2 (90,3% and 89,9%)which were taught using variant A. This fact has brought us to the conclusion that variant A is more effective.

The data were processed using the methods of statistical analysis. The results of the competences levels were united and the average quality results for EG1, EG2 ($\overline{x}$) and for EG3, EG4 ($\overline{y}$) were calculated: $\overline{x}$=67,8, $\overline{y}$=67,5 before the experiment and $\overline{x}$= 90,1, $\overline{y}$=87,9 after the experiment.

The sample estimates of the tests results allowed defining the level of professional and foreign language competences before and after the experiment. We admitted that the mean indexes of the competences levels are distributed according to the normal law.

Using the experiment data the sample mean values and the sample values of dispersion were determined as following:

- before the experiment

$$\overline{x} \approx 67{,}8, \quad \overline{y} \approx 67{,}5 \tag{1}$$

$$S_x^2 \approx 85{,}12 \quad S_y^2 \approx 58{,}24 \tag{2}$$

- after the experiment

$$\overline{x} \approx 90{,}1, \quad \overline{y} \approx 87{,}9 \tag{3}$$

$$S_x^2 \approx 41{,}11 \quad S_y^2 \approx 67{,}5 \tag{4}$$

To compare expectation values $M[X]$, $M[Y]$ the t-distribution with several degrees of freedom $k = n_x + n_y - 2$ [20] was used.

For the confidence probability $p = 0{,}95$ the critical value from the table of Student's t-distribution is $t_{50;0,05} = 2{,}00$ [24].

The calculated value before the experiment $t \approx 0{,}11$ was lower than the critical table value $|t|<t_{50;0,05}$ (0,11<|2,00|). This proves the absence of deviations of mean values before the experiment. After the experiment the calculated value ($t \approx 3{,}2$) exceeded the critical table value $|t|>t_{50;0,05}$ (|3,2|>2,00). Since the calculated value t exceeds the critical table value we can conclude that the experimental teaching of the students of experimental groups on the basis of integrated model using ICT has influenced the expected level of professional and foreign language competences.

Using F-test to check the hypothesis about the equality of dispersions of random variables X and Y allowed the confirmation of the fact that the different initial level of professional and foreign language competences before the experiment changed greatly after the experiment, since the dispersion of the results decreased.

The table of F-distribution $F_{(\alpha,k_1,k_2)}$ for the level of significance $\alpha=0{,}05$ and the degrees of freedom $k_1=k_2=n-1=26-1=25$ is equal to $F_{(0,05;25;25)}=1{,}96$ [24]. The calculated value $F = \frac{67{,}5}{58{,}24} \approx 1{,}3$ for EG3 and EG4 do not exceed the table $F<F_{(0,05;25;25)}$

(1,3<1,96). Since the calculated value $F = \frac{85,12}{41,11} \approx 2,07$ for EG1 and EG2 exceeds the table one $F > F_{(0,05;25;25)}$ (2,07>1,96), the hypothesis about the equality of dispersions is withdrawn, that is the dispersion level changed greatly.

The use of F-test allowed the confirmation of the fact that after the experiment the level of dispersion of the results of building the professional and foreign language communicative competences among the students of experimental groups has significantly decreased. This fact proves the stable competence level and consequently supports the statement about positive influence of the developed model of teaching using ICT. The dispersion of the random variables X and Y prove that the results in groups EG1 and EG2 (taught according to variant A) are better compared to the results of groups EG3 and EG 4 (taught according to variant B).

The analysis and comparison with results of contemporary researches in the field of integrated learning using ICT and the own teaching experience at higher education institution prove the necessity of interactivity of the teaching process to provide communicative interrelation of all participants, self-control and self-correction. The second important characteristic of teaching disciplines in English using ICT is their technical characteristics and didactic opportunities for lectures, seminars, practical classes and individual work. Using ICT in teaching subjects in English opens new methodological perspectives of developing degree and subject programs for future managers.

The answers of the students to the open-ended questions revealed some negative factors that could decrease the efficiency of teaching process. Some students consider the instructions delivered in Moodle insufficient and require more personal instructions. Other students feel that using of the Internet during classes distracts them from the topic of the class. The ambiguous opinions provided by the students requires further interpretation and more profound research that can become the grounds for the development of teaching techniques based on using ICT.

5 Conclusion

The research attempted in a comprehensive way to solve the problem of the rationalization of the process of both professional and language teaching of future managers on the basis of innovative efficient educational technologies stipulated by the contemporary requirements and real conditions of the higher school education.

The solution of the practical tasks of the contemporary education with the increasing role of individual work the authors connect with implementation of ICT at the lessons and for independent work, development of new principles, strategies and methods of teaching within the framework of integrated learning. These novelties can be applied when teaching professional subjects and foreign language and will provide effective learning process aimed at acquiring the necessary competencies.

The research has allowed generalizing the experience of implementation of contemporary innovative technologies in the integrated teaching of the core courses and foreign languages. The use of ICT in didactic materials provides great opportunities for all participants of the education process, consequently leading to quality improvement. The developed integrated model of the course programs "Corporate Social Responsibility" and "English for Professional Purposes" using ICT has proved the synergy effect allowing the effective acquisition of professional information on the one hand and the development of both professional and foreign language skills on the other hand, what ensures building the professional competence as a whole. The effectiveness of the model was experimentally proved after the processing of statistical data obtained in the course of the experiment. The results of the experiment can be used in developing of the recommendations as to using ICT in integrated teaching of core courses and foreign language to future managers.

Considering the overall positive result of our experience we believe that negative factors are to be given a profound research and thorough analysis. In general efficient ICT using requires great efforts of the faculty in avoiding the negative factors.

Use of ICT in the learning process should be rational and carefully designed depending on the type of lesson (lectures, seminars, practical classes or individual work), the specifics of the discipline, the goals and objectives of the teaching. Being not comprehensive, the conducted research outlines the perspectives of further investigating the crucial aspects of the organization of teaching using ICT.

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Identification of IT Sector Stakeholder's Requirements to Masters Program in Information System in Lviv Region

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Abstract. The overall objectives of the study were to research the competences required by the graduates of master program in Information System (IS) to be effectively employed by the IT companies and to develop master program in Information System (IS) reflecting those requirements. Therefore, we conducted the survey among the main stakeholders of IT sector (employers and graduates of IT specialists) to identify their requirements to the IS program. The results of the survey appeared to be different for various Ukrainian regions. To be more specific, the requirements to IS program for Kherson region (mostly managerial skills) are different from the requirements to IS program in Lviv region (both technical and managerial skills). According to Tuning approach, the results of the survey were used as the ground for the development of master's program in Information System. As the outcome of the survey the core courses, which should be the part of IS program in every University participating in the project, were determined and elective courses which cover competences required in the specific region were selected. The findings of the study would be useful both to the Universities delivering master's in IS and to the practitioners in order to respond to the labor markets needs.

Keywords: Information System, Employers, Graduates of IT Specialists, Stakeholder's Requirements, Curriculum, Lviv Region.

1 Introduction

Today, one of the key trends in the development of modern enterprises is the introduction of effective information management systems that allows monitoring and optimization of all stages of company product value chain. Implementation of modern information systems at Ukrainian enterprises requires specialists with specific competencies that are not currently on the market. These competences include [1, 2, 3]:

- project management skills for the implementation of information systems,
- the ability to carry out strategic analysis and planning of information systems,

- risk management in the design and implementation of information systems,
- creative approaches to solving problems associated with the implementation of information systems,
- the ability to design an information system corresponding to the processes and interconnections occurring at the enterprise,
- etc.

Training of specialists with such competencies will enable the first to gain a competitive advantage by obtaining the knowledge and skills that are currently not sufficiently represented at the labor market of Ukraine.

In Ukraine, and in particular in its Western region, the educational supply of specialists in the field of information systems for company management is insufficient. Moreover, in the context of the rapid development of the Ukrainian IT industry, which is largely focused on providing outsourcing services, the share of projects that involve the development of information systems for the management of Ukrainian companies is steadily increasing. Therefore, the introduction of educational program in IS developed considering modern trends will contribute to the solution of problems stated above. In particular, the development of an educational program in Information Systems will enable us to meet the needs of large and small Ukrainian companies in specialists of IS profile and will help to increase the competitiveness of our graduates in the Ukrainian and world labor markets.

Currently, the most widespread approach to the development of educational programs the European Higher Educational Area is the one based on Tuning recommendations [4]. Such approach anticipates initial identification of requirements to educational program set by the stakeholders, development of learning outcomes and competences as the result of study and selection of courses expected to cover determined learning outcomes and competences.

The current paper is based on Tuning approach and contributes to academic and practical debates by identification of the IS specialist competences required by the stakeholders and building of the educational program using this information.

2 Pre-Research

Lviv is one of the main centers of the IT industry in Ukraine, which includes more than 200 IT companies. Four large (over 400 employees), a lot of medium (120-300 employees), and small (10-100 employees) companies are among them. About 90% of Lviv IT companies are outsourcing [5], while others are outstaffing and product companies.

Lviv IT companies work in the areas where people are mostly open to outsourcing. The city is rich in IT talents, while poor in IT businesspeople. The main problems that arise in the activity of Lviv IT companies are the following [6]:

- low rates of IT market development;
- headhunting;
- an insufficient number of IT events, conferences, hackathons etc.;
- lack of office space.

According to the research [6] today, there are more than 16 000 IT professionals and more than 5 000 freelancers and employees of IT departments in companies from other industries of the city. There are about 60 IT professionals by 1000 people of working population in Lviv. Approximately 48% of them obtained full higher education in IT and more than 18% of them work in their own IT startup companies [6].

Another important issue connected with popularity of IT sphere is the existence of the IT cluster. It includes the biggest IT companies and several technical higher educational institutions with innovative training capacities in the city of Lviv. The turnover of IT industry in Lviv is 14.4% of total GDP of Lviv city [5].

Currently in Lviv, there are 8 higher educational institutions with III-IV levels of accreditation and 10 colleges that train IT professionals. One of eight higher educational institutions of Lviv is Lviv Polytechnic National University (LPNU), where Institute of Computer Science and Information Technology provides the educational program in IS [7].

In addition, the first specifically IT higher educational institution of Ukraine is Computer Academy «IT STEP» which began its operations in Lviv in 2017. Among its main advantages is the newly created IT master's program in Data science and Artificial Intelligence. However, there are some problems connected with human capital of Lviv IT sector, which are the following [8-11]:

- shortage of skilled personnel;
- lack of knowledge of the English language;
- non-compliance of competencies acquired at the university to the real needs of business;
- insufficient level of creativity of young IT employees.

Based on the information presented above we can conclude that considering the large number of IT educational institutions, the growing demand for skilled professionals and relatively developed infrastructure of IT market, Lviv became a major center of the IT industry of Ukraine. Taking into account the problems of human capital especially regarding the quality of education, there is an urgent need to improve its efficiency. Realization of the latter is possible through the close interaction with IT employers and graduates employed by Lviv IT industry. Such approach will lead to the identification of essential competencies required from IT professionals by IT market companies.

3 Stakeholders Requirements

As it was mentioned earlier the working group of the MASTIS project applied the recommendations of Tuning methodology for the development of the master's program in IS [4].

According to the recommendations of Tuning, the key tasks of the development of educational programs is a preliminary analysis of market demand and the competences that should be obtained by specialists in the field of Information Systems.

To identify the requirements to master's program in IS the following stakeholders were targeted: IT employers and the University alumni in IT.

First, we present the results of survey conducted among IT employers. In order to do that in the framework of MASTIS project [12] we determined the potential employers in the region who are the main stakeholders [13, 14] in the training of highly qualified IT specialists. The identification of such employers allowed the MASTIS project group to conduct the survey target group. The list of large and small IT companies of Lviv region involved in the development of competencies for the master's program in Information Systems is presented in Table 1.

Due to the small number of large and small IT companies in Lviv region, it was not possible to conduct the statistical analysis of the survey. According to the expert advice [15, 16], when it is impossible to obtain data from large statistical sample, the organization of face-to-face meetings with the respondents is essential. Such approach permits to get deep understanding of the problem by interviewer from the discussion with the respondent.

Table 1. Large and small companies, which participated in the survey

Company name	Company main activities	Company size
WebCodium	Web Development	small
EPAM	Software development	large
Exoft	Desktop, web and mobile development	small
SoftServe	Software development and consultancy services	large
ArtBrains Software	Development and maintains of business software solutions	small
Lohika	Software development	large

Thereafter, a series of meetings with the representatives of IT employers to conduct in-depth interviews were organized.

The other important aspect of the study is that to increase the effectiveness of the survey the experience of international project partners was considered. In particular, the analysis of various international educational programs in Information System shows that competences required in this program are both technical and managerial. In particular, such situation is in the educational programs of the following universities: University Lyon2 [17], France, Guido Carli Free International University of Social Studies [18], Italy, University of Muenster [19], Germany, University of Maribor [20], Slovenia and University of Agder [21], Norway. This information and Global Competency Model for Graduate Degree Programs in Information Systems (MSIS 2016) [22] were used to develop questionnaire for the study. MSIS 2016 is a set of competencies that the students are expected to obtain as the result of master's program in Information Systems. MSIS 2016 was developed by an international team of experts from the USA, Singapore, Ireland, Portugal etc.

The MASTIS project team prepared a questionnaire containing nine competence areas with subclasses based on MSIS 2016. To answer the survey questionnaire the 1 to 5-point scale was suggested for use to the survey respondents. The scale mark “5” is interpreted as the highly important competency for IS program graduates, and the scale mark “1” is defined as the least important.

The results of the survey were summarized and grouped by large (yellow column histograms) and small (blue column histograms) companies (see Fig. 1).

The project colleagues from Kherson conducted the similar survey among the employers of their region. The results and interpretation of their survey are presented in [23]. The next step of our analysis was to compare of the employer’s evaluation of each competency area in Lviv and Kherson regions. The results of comparison are presented on Fig. 2.

As the result of analysis of data presented at Fig 2 we can conclude that employers of the Lviv region emphasized the importance of both technical and managerial competencies (areas 1-3, 9). Such situation may be explained by the fact that the best graduates of IT specialties usually become employers as their careers develop. At the same time, this group of stakeholders represents Lviv region large and small IT companies who are actively engaged in the practical design of information systems and conducting operational company management.

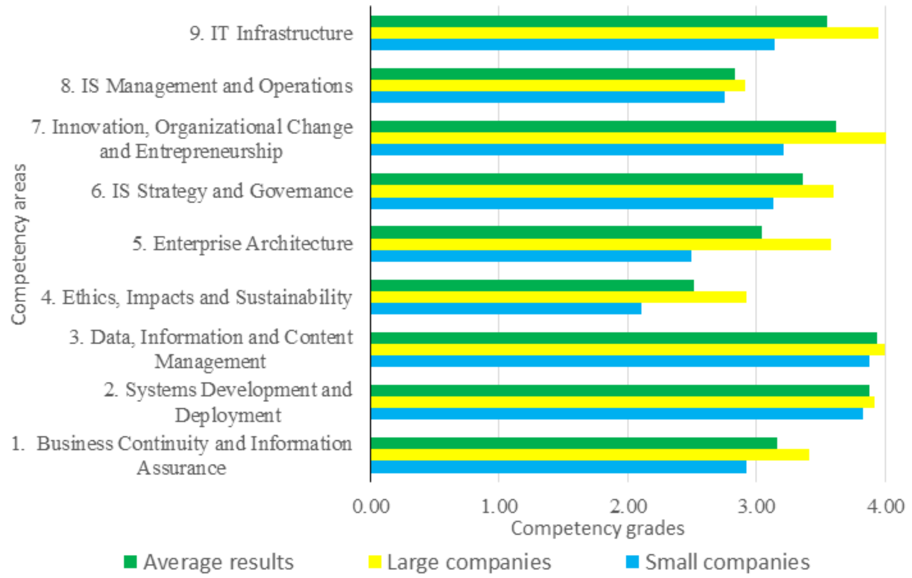

Fig. 1. Grading of IS competence areas by the representatives large and small IT companies of Lviv region.

Employers of Kherson region stated that the Information System specialists should have a narrower knowledge and skills. According to the opinion of Kherson region employers the master’s program in IS should be more focused on the following competency areas: ethics and sustainable development, enterprise architecture, information systems strategy and management and innovation, organizational change and entrepreneurship.

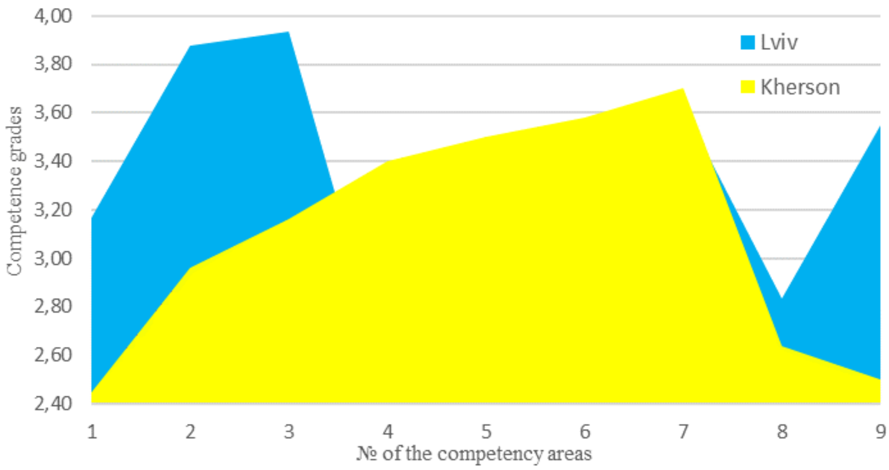

Fig. 2. Comparison of employer's survey results in Lviv and Kherson regions.

There is the other conclusion of the surveys. The employers of both regions suggested that competencies from "4-7" areas should be covered by courses of master's program in IS. In addition, the comparison of surveys permitted the project team to conclude that as a part of MASTIS project a set of core courses required in both regions can be developed.

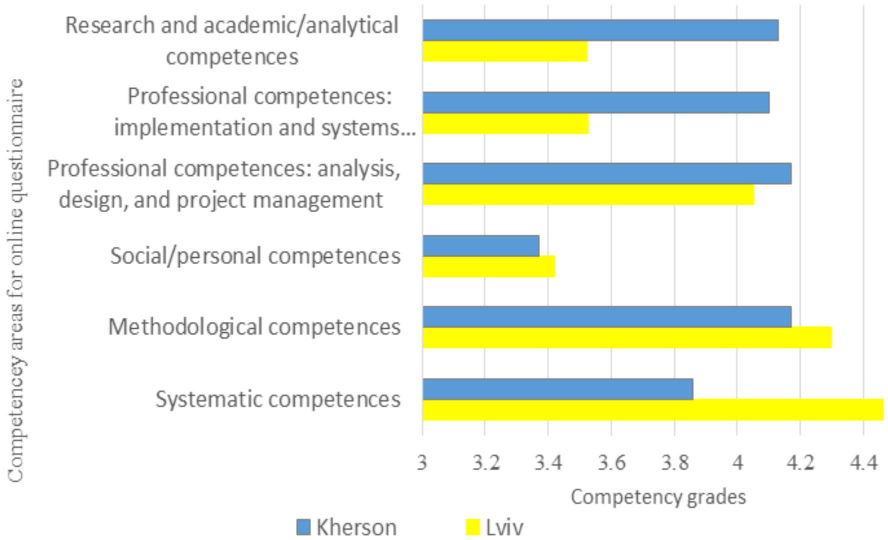

Fig. 3. Comparison of the results of the online survey for graduates of IT specialties in Lviv and Kherson regions. Source: based on the survey conducted in Lviv region by the article authors and Kherson MASTIS team in [23].

In order to increase the probability of data obtained as the result of in-person meetings, an online survey among the University graduates in IT was organized. For this purpose, an online questionnaire for graduates of IT specialties in the Lviv region was elaborated. The results of the comparison of online surveys conducted in Lviv and Kherson regions are presented on Fig. 3. It demonstrates the most important competencies according to the opinion of graduates of IT specialties of both regions.

4 Curriculum Development Based on Survey Results

The results of the survey were used to develop IS Master's Curriculums for each University-member of MASTIS project consortium. As a part of MASTIS project, the method of IS Master's Curriculums development anticipated the elaboration of core and elective courses. Eight suggested core courses are expected to be delivered in all project partner universities. The core courses are the result of identification of the most important competencies suggested by both groups of stakeholders from all regions of the partner Universities. In the same time, to present dissimilarities of stakeholder survey opinions for different regions of Ukraine, partner Universities developed elective courses.

Therefore, based on the survey's results for Lviv region Lviv Polytechnic University MASTIS team developed a set of courses that meet the needs of specifically regional IT companies. On the Table 2 some elective courses and relevant to them competency areas corresponding to the needs of Lviv region are presented. The set of core courses elaborated as a part of MASTIS project, is not included into the current paper.

Table 2. Some elective courses of new IS Master Curriculum.

Course	Competency areas
Professional and civil security	1. Business Continuity and Information Assurance
Innovative information technologies	2. Systems Development and Deployment
Data and knowledge engineering	3. Data, Information and Content Management
Information resources integration technology	9. IT Infrastructure
Information Management and Marketing	7. Innovation, Organizational Change and Entrepreneurship

To cover the technical competences necessary to the IS Specialists in Lviv region the following courses were developed: Professional and Civil Security, Innovative Information Technologies, Data and Knowledge Engineering, Information Resources Integration Technology. In the same time managerial competences will be developed in the IS students as a part of Information Management and Marketing course.

The suggested courses will cover both the technical and managerial competencies required by IS specialist to be successfully employed at Lviv Region IT-market.

5 Conclusion

The paper provides an insight into the determining managerial and technical competences for the development of master's program in IS. The competences were identified as the result of the survey conducted among employers and IT-specialties graduates. The complete list of competencies identified as the result of the survey helped to create a new master's program in Information Systems.

The methodology developed in this paper has several practical implications. The paper outlines the necessity to develop the courses in accordance to the competencies required by stakeholders. The competence approach to development of IS master's program was based on meetings (interviews) with the employers of the Lviv and Kherson regions and on on-line survey of IT-specialties graduates employed by IT companies. The results of the survey provides Universities participating in the project with a profound understanding of the most essential competencies required by IT labor market. The key contribution of this paper is provision of a detailed starting point towards the development of master's program in IS with a clear list of managerial and technical competences and relevant to them courses. Students will benefit from the courses taught at master's program in IS through continuous development of their competences based on requirements IT sector of particular region. As the result, students will have a chance to be successfully employed by IT companies of the relevant region.

6 Acknowledgements

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Using the SlideWiki Open Education Platform

Invited Tutorial Abstract

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Abstract. SlideWiki's goal is to revolutionise how educational material is authored, shared, and reused. By enabling authors and students to create and share slide decks as HTML in an open platform, communities around the world can benefit from materials created by world-leading educators on a wide range of topics. SlideWiki is an open source project, funded from the European Union's Horizon 2020 research and innovation programme. The project involves 17 partners who are developing, testing and trialling SlideWiki. In this tutorial we give a description of the platform and its main functionalities combined with a hands-on session. We will demonstrate how to use SlideWiki as an educational professional, industry professional, or as a user contributing to open educational material. We will detail how existing educational material can be imported in SlideWiki, how it can be edited and re-used in a collaborative setting, and how it can be exported to various formats and learning management systems. Participants will get familiar with the version management, translation, annotation, searching, editing, and presentation features in SlideWiki by using these in practice in an interactive way. We illustrate above with real-world examples from our experience in using and developing SlideWiki. Presentation of features will be followed by hands-on activities in which the participants exercise the use of the concepts explained. The tutorial is aims to have participants be able to do the following: (i) use SlideWiki to import educational material, collaboratively create educational material, and export educational material to various formats; (ii) use the presentation features of SlideWiki, including the more advanced interactive presentation room; (iii) use other advanced SlideWiki features, including group edit rights, forking decks, questions and exams, and applying templates and themes.

Keywords: open education platform, SlideWiki, open source, open educational material, learning management system

Blockchain Technology and Applications

Tutorial Abstract

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Abstract. A blockchain is a public ledger to which everyone has access but without a central authority having control. It is an enabling technology for individuals and companies to collaborate with trust and transparency. One of the best know applications of blockchains are the cryptographic currencies such as Bitcoin and others, but many other applications are possible. Blockchain technology is considered to be the driving force of the next fundamental revolution in information technology. Many implementations of blockchain technology are widely available today, each having its particular strength for a specific application domain. The tutorial provides the participants with insights and practical experience on Blockchain technology and applications in practice, as well as theory based exploration of possible business cases.

Keywords: Blockchain, Bitcoin, Cryptographic currency, Blockchain applications

1 Introduction

A blockchain is a public ledger to which everyone has access but without a central authority having control. It is an enabling technology for individuals and companies to collaborate with trust and transparency. One of the best know applications of blockchains are the cryptographic currencies such as Bitcoin and others, but many other applications are possible. Blockchain technology is considered to be the driving force of the next fundamental revolution in information technology. Many implementations of blockchain technology are widely available today, each having its particular strength for a specific application domain.

The tutorial provides the participants with insights and practical experience on Blockchain technology and applications in practice, as well as theory based exploration of possible business cases.

2 Theme and Topics

The target audience will be students and researchers interested in Blockchains, the underlying concepts and technologies, its impact on business models and possibilities for process improvement, as well as practitioners aiming to learn theory and practice on Blockchains.

The tutorial is self-contained and derived from a winter school/summer school organized by HU University of Applied Sciences Utrecht

The tutorial will cover the following topics:

- Introduction to blockchains: what is a blockchain, what cryptographic technologies are used, why does it work?
- Digital currency: how are blockchains used as the backbone technology for digital currencies like Bitcoin?
- Smart contracts: what is a smart contract, how can it be used?
- Etherium and solidity: a short introduction to Etherium and its programming language solidity.
- Discussion: wrap-up and discussion about the topics presented.

3 Related Courses

The material presented in this tutorial is also taught in a 5 day track at our Winter and Summer schools. One may refer to https://www.utrechtsummerschool.nl/courses/business/blockchains-theory-and-practice for a more detailed information. The tutorial contains information presented during these 5 days, but is of course much more limited in detail.

Design Patterns for Object-Oriented Scientific Software

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Abstract. Software design patterns are general reusable object-oriented solution. In software engineering, patterns have been proven to offer many benefits. Scientific software also becomes more object-oriented and the importance of design patterns increases. We present a set of design patterns for object-oriented scientific software. Particularly we develop computer-aided engineering software based on the Finite element method. Initially, we decompose the problem into subsystems by applying the commonality and variability analysis. A set of commonalities includes following terms: a representation scheme, a mesh, a solver, etc. A representation scheme is an interface that allows to check whether a point belong to a solid or not. A mesh is the discrete representation of the solid via a set of simple geometric shapes. Four basic design patterns for the scientific software development have been presented in this paper. There are developed UI–Model–Analysis, Representation–Mesh, Element–Mesh, and FEA Problem patterns. These design patterns separate pre-processing, the analysis solver, and post-processing of results.

Keywords: Software Engineering, Software Design Patterns, Scientific Software, Finite Element Method, Object-oriented Approach.

1 Introduction

Software design patterns as general reusable solutions were introduced in the end of the 1980s and, since that time, they have been actively explored in software engineering [1-3]. Until recently, scientific programmers have usually avoided object-oriented approaches because of their heavy computational over-head [4]. However, scientific software becomes larger and requires flexibility, extensibility and maintainability [5]. Design patterns deal with these issues providing generic object-oriented solutions.

CAE software is a kind of scientific software that areas may include the stress analysis, the thermal analysis, the fluid flow analysis, the multibody dynamics etc. In general, a CAE system consists of three subsystems: pre-processing, an analysis solver, and post-processing of results.

2 Catalogue of Design Patterns

Consider a generic CAE system that uses the finite element method in the solver subsystem. We can assume that every solid's model is initially defined by some representation scheme and then this model is discretized into a mesh.

2.1 UI–Model–Analysis Pattern

The most modern CAE software have integrated graphical user interface (UI). Using UI controls, user defines the model of the problem and performs the analysis. Hence, three main packages participate in the high-level decomposition.

The UI package contains classes that implement UI-related responsibilities of software. The analysis package is responsible for the numerical analysis. The model package defines the interface that allows to check whether a point belong to a solid or not. Naturally, there should be no coupling between the analysis and UI subsystems. However, the UI package is dependent on pre-processing, the solver and post-processing.

2.2 Representation-Mesh Pattern

We suppose that a domain model is described in terms of some representation scheme. Boundary representation (BRep), constructive solid geometry (CSG), and function representation (FRep) are the most commonly used schemes. A common property of CSG and FRep that it is easy to check whether arbitrary point belong to the solid or not. We also can assume that a mesh is an abstract interface that allows generating and iterating over a collection of elements. In this case, concrete classes derived from the Mesh class generate collections of elements with appropriate shape using an abstract representation' interface to classify a point. Both Representation and Mesh classes participate in the Representation–Mesh pattern (see Fig. 2). The intent of this pattern is to separate responsibilities between representations and mesh generation classes.

Both Representation and Mesh classes are an application of the Strategy pattern [1]. The Mesh class and its derivatives can also be implemented as Iterator [1] to traverse a collection of elements. In addition, some meshing algorithms may be implemented as Template Methods [1].

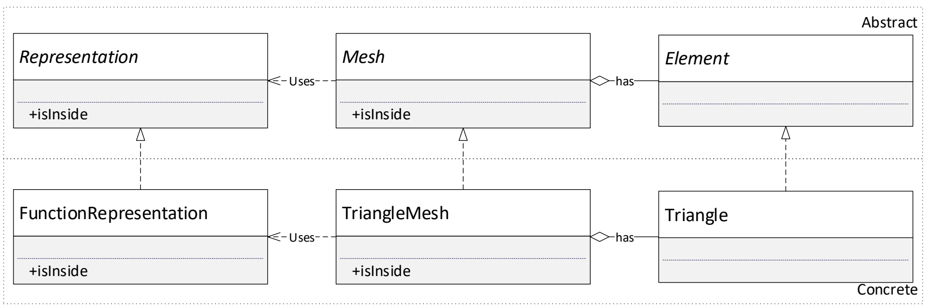

Fig. 1. The Representation–Mesh pattern

2.3 Element–Node Pattern

In general, an element is a collection of nodes in order is significant. Both two- and three-dimensional elements have edges (an edge is a straight-line segment connecting two nodes). In addition, three-dimensional elements have faces that are flat elements enclosed by edges. Thus, the concrete face is an object of the class that inherits the Element interface. Hence, Element, Face, Edge, and Node are structural elements of the Element–Node pattern (see Fig. 2).

The Element class and its derivatives (including faces) can be implemented as Iterator [1] to traverse collections of points and edges. The Iterator pattern can also be employed in the Node class and its derivatives to iterate a set of adjacent elements.

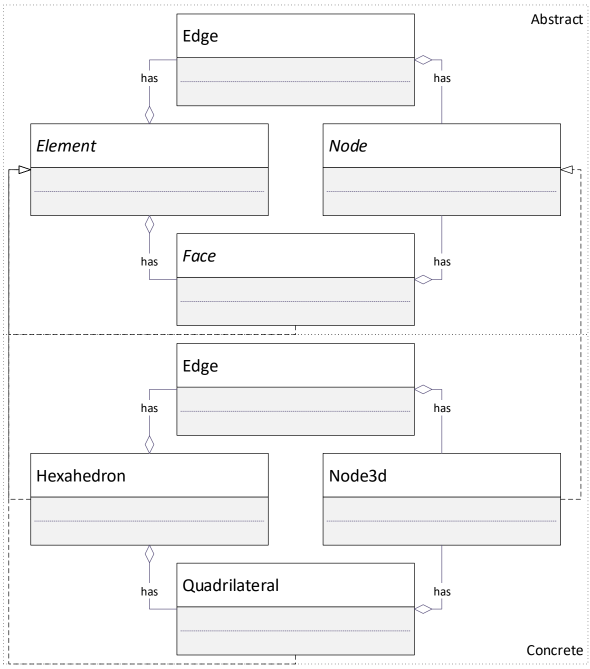

Fig. 2. The Element–Node pattern

2.4 FEA Problem Pattern

The FEA Problem pattern can be derived from the Template Method Pattern [1] adding mesh, boundary conditions, and forces (see Fig. 3). The intent of this pattern is to define a skeleton of a FEA algorithm and the object composition for boundary conditions and forces, which participate in the problem.

Forces and boundary conditions implement the FeaValue interface. This interface allows to obtain the direction and the value in any point. Forces and boundary conditions are usually specified by the UI or DSL model. However, using the Adapter pattern [1], we can implement the FeaValue interface.

3 Conclusion

This paper has been proposed an approach for the development of scientific software using design patterns. Particularly, four basic design patterns for the finite element programming have been presented in this paper. The first, the UI–Model–Analysis pattern decomposes software into high-level subsystems. The second, the Representation–Mesh pattern separates relations between representations and mesh generation classes. Next, the Element–Node pattern uses object decomposition to define elements of a mesh. Last, the FEA Problem pattern defines the structure for a generic finite element problem. These patterns show how object can be organized for greater flexibility and maintainability. Patterns represent abstractions of the CAE design without restrictions on the source code.

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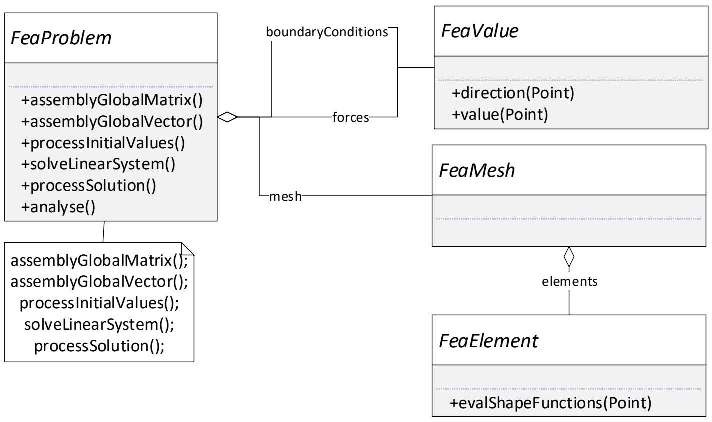

Fig. 3. FEA Problem Pattern

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Automation of Assessing the Reliability of Operator's Activities in Contact Centers that Provide Access to Information Resources

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Abstract. Aautomated systems with many active operators such as contact center of providing internet and television services are researched. To describe the activities the functional structural theory of ergotechnical systems of Prof. A.I. Gubinsky was used. Estimation model of the human-operator reliability were obtained. Computer experiments were conducted. Results will be useful in improving the ergonomic properties of contact-center of providing internet and television services.

Keywords. Contact-center, man-operator, ergonomics, information technology, human factor, human-machine, effectiveness, reliability.

1 Introduction

Progress and strong competition in providing information and computer services for legal entities and individuals in local and global networks exacerbate problems of quality and operational services. Huge efficiency reserves are in the modern arsenal of ergonomics methods [1–6].

2 Problem Statement

In this regard, the purpose of this work is: Based on real system analysis, which provides access to the resources of computer and television networks: - to explore all organizational options of operators activity including serving the applications for the formation of new information services and for the elimination of services quality violations; - to substantiate the method of describing and assessing options of operator activities structures; - to develop a computer program to simulate the activities of operators; - to demonstrate the possibility of using developed models in providing access to resources of computer networks systems.

3 Approach

3.1 Brief Analysis of the Activities of Contact Center Operators

Research of internet access services and other telecommunication systems (PortaOne, NetCracker, Efsol) revealed: - algorithmic nature of the operators’ work; - presence of alternative algorithms in applications execution; - significant influence of operator’s skills and their working conditions on the quality of work.

At the same time most often there is no "hint system" of appropriate operators’ behavior strategies, based on time calculations and accurateness of the action options.

In modern companies, as a rule, there is keeping of time and error-free records of operators’ actions and operations. If we analyze all possible activity structures, their description and statistical quality data, we can estimate the time and the accurateness of incoming applications implementation.

3.2 Operators Activity Modeling

Mathematical Apparatus for Modeling. The most convenient algorithmic activity modeling way is functional-structural theory (FST) of ergotehnical systems (ETS) by prof. A.I. Gubinsky [7]. The description of elementary actions of operators is carried out with the help of standard functional units (TFU). A complete list of TFU is given in [7]. The functional network (FN) that describes the activity of the human-operator is built from these TFU. Mathematical models for accurateness and run-time estimation are obtained for typical functional structures (TFS). These models are used to evaluate the entire FN. The estimation is carried out by the method of folding (reduction) FN [7].

Description and Evaluation of Alternative Implementation Options for the Functional Element of Processing Customer Applications. Operator’s activity organization in the sphere of public Internet services is considered. Operator implements the application for "services restoration". This activity can be represented as an algorithm of operation groups: - service application reception; customer's problem analysis; solution; informing the client about the results of the implementation. Formal models are obtained in the form of FN are obtained for the implementation of such activity algorithms: problem 1 - limited Internet access due to the failure to notify about payment; problem 2 - lack of Internet access (due to the client hardware problem); problem 3 - lack of Internet access (due to the company's equipment problem); problem 4 - restricting access to digital television due to the non-payment.

Since working conditions substantially affect the operational quality [1,4,7], we use the correction factors method [7,9–11]. We will use software package [8] for determining these values and evaluation of the functional network of the activity algorithm.

Evaluation of the functional network is based on the technology of functional structures typing and function network folding. The structure of the software is shown in Fig.1.

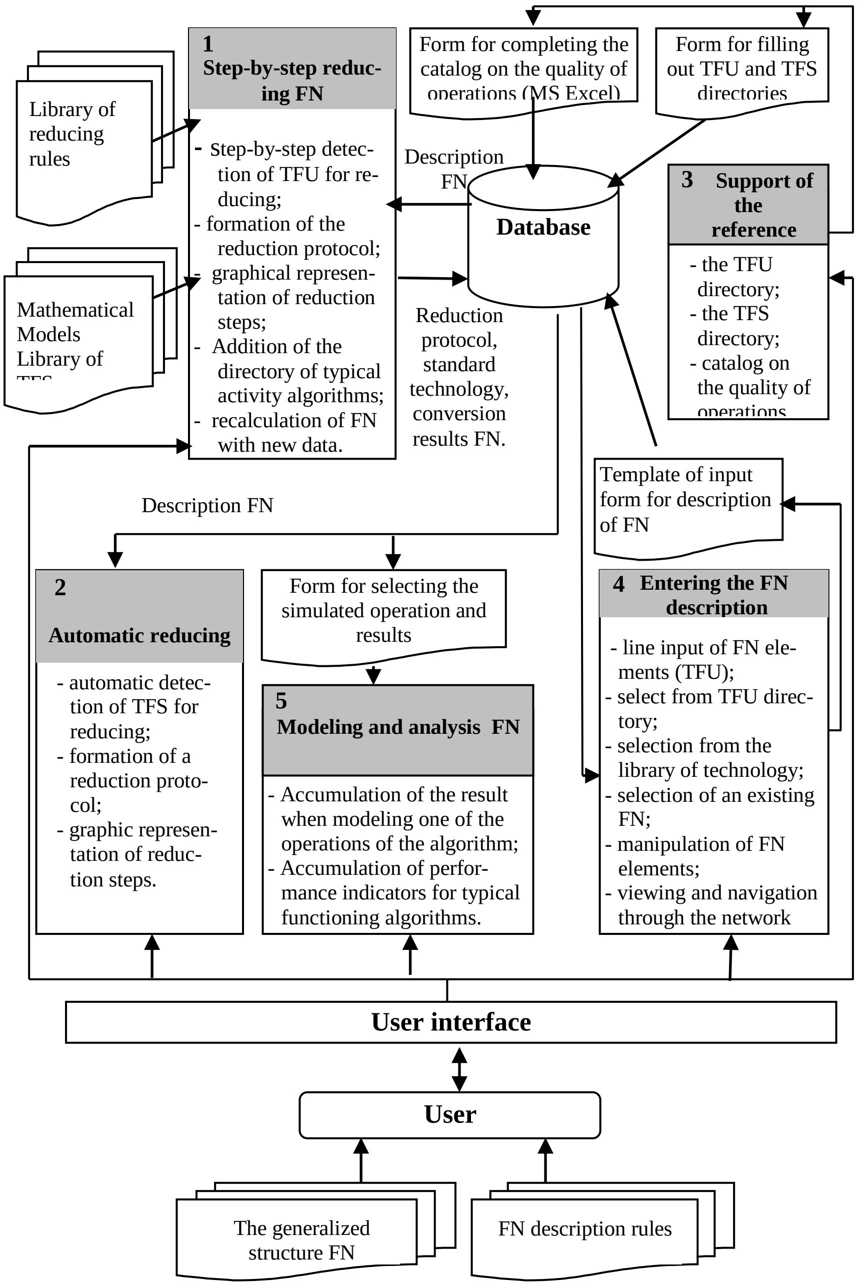

Fig. 1. The functional structure of the FN assessment program

4 Conclusion

The developed approach allows formal describing of the algorithmic operations; also it helps to evaluate a random amount of time and the probability of error-free performance of the operational algorithms in "computer network resources assessing" systems. The advantage of this method is that it makes possible the creation of unambiguous computer-based models and numerical evaluation of various options of operators' activities. The complexity of this method includes the complicated formation of the initial data for the calculation and the necessity of conducting special statistical databases.

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Mathematical Support for Statistical Research Based on Informational Technologies

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Abstract. The authors developed "case of the information manager", which will include tools for mathematical and statistical analysis, oriented to those who have the skills of working with software only "at the user level" and implemented by means of MS Excel table processor. "Case of the information manager" includes the following methods: descriptive statistics, correlation analysis, classification and cluster analysis methods, paired comparison method, Saaty's method (algorithmic hierarchical procedure) and others.

Keywords: "case of the information manager", correlation analysis, ranking method paired comparison method, Saaty's algorithmic hierarchical procedure, hierarchical agglomerative cluster analysis.

1 Introduction

The use of information technologies in various areas of human activity has given rise to a certain interest in application of mathematical and statistical methods in humanitarian field, particularly, for library staff - information managers. Without good mathematical training, they often use simple methods to improve their work, using, in spite of this, personal computers and elementary mathematical support of MS Excel spreadsheet. In essence, this situation creates an actual scientific problem, the meaning of which in the development of a special manual on the application of mathematical methods for library workers. The aim of this work is the selection of simple and effective mathematical and statistical methods for mathematical study of decision-making information manager. The first among these methods are methods supported by information managers and are the following: correlation method, method of ranking, method of pair comparisons, Saaty's analytic hierarchical procedure and the hierarchical agglomeration cluster analysis. These methods are implemented by a simple step-by-step algorithm.

2 Correlation Analysis

This method has been used to determine the differences between reading rooms in relation to their attendance by readers. As data, the number of visitors per room per month is taken. Mutual and partial correlation coefficients were determined. The names of reading rooms and calculation results are given in Table 1.

Table 1. The results of correlation analysis.

Relationship between the reading room № 1 and the room of abstracts № 2	Relationship between the reading room № 1 and the room of patents № 3	Relationship between the room of abstracts № 2 and the room of patents № 3
R_{12} = 0.689	**R_{13} = 0.823**	**R_{23} = 0.688**
The coefficient of partial correlation of rooms № 1 and № 2 relatively to the room № 3	The coefficient of partial correlation of rooms № 1 and № 2 relatively to the room № 3	The coefficient of partial correlation of rooms № 1 and № 2 relatively to the room № 3
$R_{12.3}$ = 0.297	**$R_{13.2}$ = 0.664**	**$R_{23.1}$ = 0.293**

Thus, it can be approved that the reading rooms № 1 and № 3 are more similar concerning visits.

3 Ranking Method

The simplest method to evaluate the impact n factors by determining their weight, i.e. setting their ranking is the method of ranking. The essence of this method is represented by the following example. It is necessary to determine in what order in the instruction to put 7 rules for use of reader fund. Participants in the ranking were the 5 specialists. To solve this, a group of specialists was invited. Each of them gives an assessment of the place of the rule on 10-point scale. The results of the method are shown in Table 2.

Table 2. Determination the order of the instruction items.

Rules	P1	P2	P3	P4	P5	P6	P7
Points	18	17	33	35	26	23	20
Weights	0.10	0.10	0.20	0.20	0.15	0.13	0.12

The rules in the instruction must be in this order: P4, P3, P5, P6, P7, P1, P2. Though P1 > P2 and P4 > P3, presented values of their weights are equal as a result of rounding. This method is the easiest to evaluate staff. The results of work of employees who are evaluated and ranked from the best to the worst or vice versa are compared. Ranking methods also make it possible to compare employees with each other according to selected criteria.

4 Paired Comparison Method

The paired comparison method is used when the group of objects must be submitted in a certain sequence, i.e., to determine the rank of each object for giving preference. For example, libraries offer 6 services, among which the most demanded must be identified. Three experts were invited. The weights of alternatives, identified by the experts, are shown in Table 3.

Table 3.

$\mathbf{V_1}$	$\mathbf{V_2}$	$\mathbf{V_3}$	$\mathbf{V_4}$	$\mathbf{V_5}$	$\mathbf{V_6}$
0.207	0.184	0.156	0.076	0.187	0.191

So, according to experts, the most demanded service is $\mathbf{V_1}$. Next are the services: $\mathbf{V_6}$, $\mathbf{V_5}$, $\mathbf{V_2}$, $\mathbf{V_3}$, $\mathbf{V_4}$.

5 Saaty's Algorithmic Hierarchical Procedure

This method involves decomposition of the problem into simple components and processing the judgments of decision maker. The essence of this procedure is quantitative expression of qualitative considerations. The structure of the problem is presented with a hierarchy, the top of which is the goal, and the levels are criteria and alternatives. The procedure includes pairwise comparisons, both criteria and alternatives. Quantitative values are estimates in the scale of relations. For example, for the post of librarian, five candidates were selected for 5 criteria: O, I, S, N, J., based on interview results for each of the criteria comprise the matrices of pairwise comparisons and defined the normalized vectors of local priorities, constructed in matrix B, and vector N for it is constructed. To determine global priorities, vector **U** is constructed by multiplying the matrices **B** × **N**. The results are shown in Table 4.

Table 4.

	B					**N**	**U**
O	0,262	0,143	0,510	0,029	0,090	0,138	0,149
I	0,075	0,495	0,033	0,059	0,255	0,113	0,109
S	0,507	0,047	0,064	0,502	0,138	0,160	**0,179**
N	0,129	0,074	0,130	0,148	0,478	0,154	0,124
J	0,028	0,241	0,263	0,263	0,039	0,113	0,118

In the last column we obtain, as the matrix product, the values of the vector of global priorities for candidates for the position of librarian **U**. Candidate **S** has the highest global priority. Thus, with the help of this analytical hierarchical procedure, candidate S is recommended for the post of librarian. This method is widely used in decision making support.

6 Hierarchical Agglomerative Cluster Analysis

In the practice of library and information managers often there are problems of splitting a group of objects into separate classes. If objects are described by identical sets of attributes, then the problem can be solved by means of cluster analysis. Clustering is often the first step in data analysis. The essence of hierarchical agglomerative cluster analysis is that in the beginning all elements are considered as separate clusters, and then the distances between these objects are determined and two of them, the closest ones are grouped together into a separate cluster. Its procedure is iterative and ends with the union of all objects in one cluster, but with a clearly defined structure, which is presented as a dendrogram. As an example, in Fig. 1 the result of the cluster analysis of a group of 20 University libraries based on 12 indicators using the distance of Euclid in the form of a dendrogram is shown. Potential clusters are marked with horizontal dashed lines - similar to each other libraries.

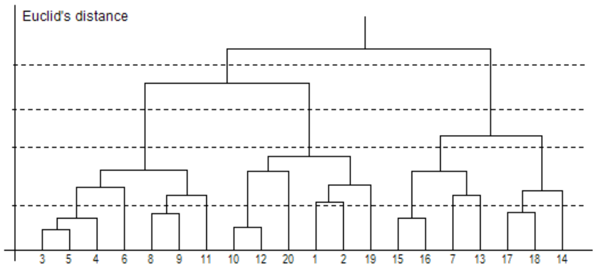

Fig. 1. Dendrogram of splitting into clusters the group of University libraries.

As a result of splitting into clusters this group of libraries, at the lowest level there are 14 clusters, at the next level is 4, then 3 and two. That is, depending on the height of the level, we have a different number of clusters.

7 Conclusions

The listed methods can be supplemented by many others, but even this set can significantly improve the efficiency of the work of the information manager. In this study, the main principle is the presentation of the method, starting with a detailed consideration of solution of specific task with it and discussion of the result. Therefore, at each stage of the used method it is necessary to give detailed interpretation of the obtained intermediate result. Practical methods verification and discussion with the direct users, confirmed the validity of this approach and effectiveness of their use in the practice of information managers.

Cryptocurrencies Prices Forecasting With Anaconda Tool Using Machine Learning Techniques

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Abstract. The research goal is to study criteria which affect the price of a cryptocurrency and their usage for the price forecasting using Machine Learning techniques. The subject of research is forecasting of most famous cryptocurrency Bitcoin using the most popular Python Data Science Platform – Anaconda. Research Methods are machine learning, data analysis, and multiple regression. A set of criteria which affect the price of the cryptocurrency were defined based on the analysis of public information. Their correctness was tested using Machine Learning algorithms. As a result of simulation experiment through the application using real data from open sources, we have found that selected combination of criterion can explain more than 70% of cryptocurrencies prices variation using either Multiple Regression or Random Trees or Long Short-Term Memory networks.

Keywords: cryptocurrency, bitcoin, forecasting, machine learning, multiple regression, random forests, lstm, long short-term memory, python, data science.

1 Introduction

The story of cryptocurrencies had started in 2009 when Bitcoin was born. It was the first decentralized digital currency with emphasis on cryptography [1]. After nine years, almost 1500 live cryptocurrencies exist [2], and their number continues to overgrow [3].

Another trending sphere that is developing rapidly in the last few years is Machine Learning (ML). It is a method of data analysis that automates analytical model building. ML allows applications to find hidden insights without being explicitly programmed [4]. One of the most common task ML solves correctly is forecasting.

The purpose of the paper is to formalize criteria which affect the price of cryptocurrencies and use them in the price forecasting experiment developed with Python Anaconda Data Science tool with ML algorithms.

The paper is organized as follows: part 2 describes dataset and ML algorithms used in an experiment and the results of the experiment, and the last part concludes.

2 Cryptocurrencies Dataset and ML Prediction Algorithms

Information about cryptocurrencies like their prices per date, their supply, mining difficulty, and other is open source. So we combined data into one dataset [5]. It has next columns:

- date, from 25th of January 2017 to 22 of January 2018 separated by weeks;
- price - the price of Bitcoin for each date (in USD);
- supply - the Bitcoin's total number of coins for each date;
- difficulty - the Bitcoin's mining difficulty for each date (hash rate)[8-hashrate];
- trading_volume - the Bitcoin's trading volume for each date;
- reaction - average society reaction on Bitcoin for each date ("-1" is negative, "1" is positive, and "0" is neutral);

Our dataset has 105 rows, and it was separated into two subsets: training and testing. 70% of data is training set (it is 73 rows) and 30% if data is verification set (it is 32 rows).

In our research we decided to use three supervised ML algorithms to verify if these criteria can be used in cryptocurrency's price prediction in such combination:

- Multiple Linear Regression with default configuration sklearn configuration;
- Random Forests with 100 trees;
- Long Short-Term Memory Networks with 50 neurons on a hidden layer and 100 epochs of training.

Linear regression shows relations between variables and how changes affect them. Random Forests algorithm uses a bagging approach to create a bunch of decision trees with a random subset of data. LSTMs are capable of learning long-term dependencies. The research question is: Which criteria affect the price of the cryptocurrency and how? We have found next points:

1. Total number of mined coins;
2. Mining difficulty level;
3. Cryptocurrency's trading volume;
4. Perceptions of the cryptocurrency's value by the society;
5. Price of Bitcoin.

After all three predictions, we were able to find mean squad error and coefficient of determination. Linear regression application output was:

```
Mean squared error: 2274869.02
R^2 score: 0.79
```

But, Random Forests application output was:

```
Mean squared error: 585482.78
R^2 score: 0.97
```

And, finally LSTM network application output was:

```
Mean squared error: 3248292.00
R^2 score: 0.80
```

In the graphic below we display the results of both predictions in contrast to real values. (fig. 3).

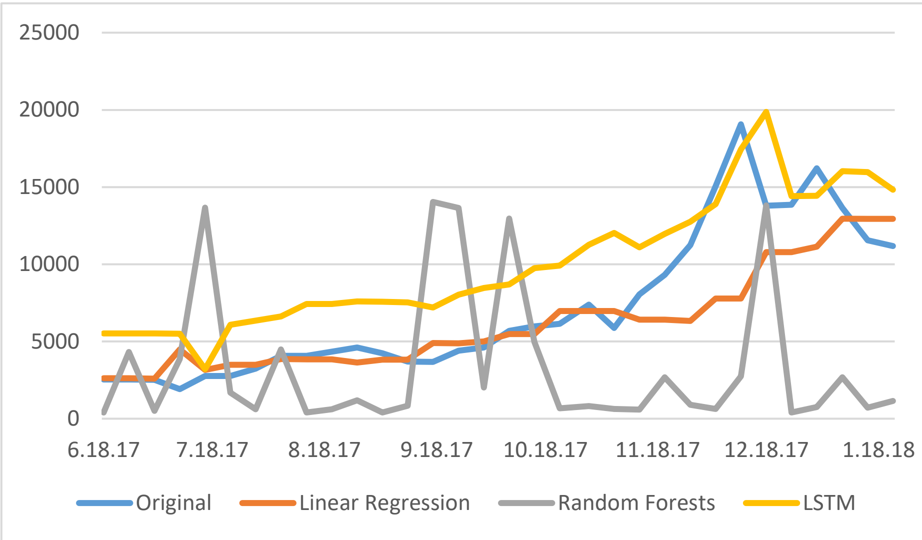

Fig. 1. Comparison of real Bitcoin prices, predicted with Linear Regression and predicted with Random Forests [6]

3 Conclusions and Outlook

Thus we have tested the correctness of the selected criteria combination on their effect on the price of Bitcoin. For our experiment, we used Multiple Linear Regression, Random Forests, and LSTM ML algorithms implemented with Python in Anaconda Data Science tool. As a result, we have found that selected combination of criterion can explain more than 70% of Bitcoin's price.

On this base, we plan to study additional criteria which affect prices of cryptocurrencies to be able to forecast their prices more accurate.

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Classification of Multifractal Time Series by Decision Tree Methods

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Abstract. The article considers classification task of model fractal time series by the methods of machine learning. To classify the series, it is proposed to use the meta algorithms based on decision trees. To modeling the fractal time series, binomial stochastic cascade processes are used. Classification of time series by the ensembles of decision trees models is carried out. The analysis indicates that the best results are obtained by the methods of bagging and random forest which use regression trees.

Keywords: multifractal time series, binomial stochastic cascade, classification of time series, Random Forest, Bagging

1 Introduction

Many complex systems have a fractal structure and their dynamics is represented by time series that have fractal (self-similar) properties. Fractal time series take place in technical, physical, biological and information systems. The results of time series fractal analysis are widely used in various fields, in particular, in recognition and classification.

The tasks of classification of fractal realizations arise when medical diagnosis clarification by ECG and EEG [1], when DDoS-attacks are detected by the incoming traffic [2], when critical situations in financial markets are forecasted by economic indicators series [3], etc. Most often, such tasks are solved by estimating and analyzing fractal characteristics. However, in recent years, there has been a growing interest in machine learning methods to analyze and classify fractal series [4-6].

Key to correctly solving the classification problem is the choice of the classification method. To answer the question which method is best for analyzing multifractal properties, we present the results of study in which the classification of model realizations possessing fractal properties was carried out. The aim of the work is a comparative analysis of the classification of multifractal stochastic time series performed by methods based on decision trees.

2 Multifractal Time Series

The self-similarity of random process is to preserve distribution law when changing the time scale. A stochastic process $X(t)$ is self-similar with a parameter H if the process $a^{-H}X(at)$ is described by the same finite-dimensional distribution laws as $X(t)$. The parameter H, $0 < H < 1$, called the Hurst exponent, represents the measure of self-similarity and the long-term dependence. Multifractal stochastic processes are inhomogeneous self-similar ones and have more flexible scaling relations. The multifractal properties of process are defined the scaling exponent $\tau(q)$. In the general case $\tau(q)$ is a nonlinear function for which the value $(\tau+1)/2$ coincides with the value of Hurst exponent H. For monofractal process $\tau(q)$ is linear. [7].

One of the frequently used models of the multifractal process is the conservative stochastic binomial multiplicative cascade. To its construction, an iterative procedure based on two main parts is used. The first represents geometric detailing by iterative partitioning of intervals, and the second guarantees randomness of the weighting coefficients. For each iteration n, $n \gg 1$, we have a time series (cascade) with multifractal properties.

The fractal characteristics of stochastic multiplicative cascade obtained using beta distribution random variable $Beta(\alpha, \beta)$ are completely determined by the parameters $\alpha, \beta > 0$ [8]. The change of value α of the symmetric distribution $Beta(\alpha, \alpha)$, allows to generate of multiplicative cascades with specified multifractal properties and Hurst parameter in the range $0.5 < H < 1$.

3 Classification Methods

The decision tree method is effective method of classification. It is applicable to solving classification problems arising in various fields. It consists in the process of partition the original data set into groups, until homogeneous subsets are obtained. The set of rules that give such a partition allows then make a conclusion for new data. However the decision tree models are unstable: a slightest change in the training set can bring to the essential changes in the tree structure. In this case, it is expedient to use ensembles of elementary classifiers. The components of the ensemble can be the same type or different.

The bagging method [9] is based on the statistical method of bootstrap aggregating. Bagging is a classification technique where all the elementary classifiers are trained and operate independently of each other. The basis of the bagging method is the classification technology, called "perturbation and combination". Perturbation is understood as the introducing of some random changes in training data and the construction of several alternative models on the modified data. From a single training set several samples containing the same number of objects are extracted by sampling. To obtain the result of the work of the ensemble of models, the voting or averaging are usually used. The effectiveness of bagging is achieved due to the fact that the basic algorithms, trained in different subsamples, are obtained quite different and their mistakes are mutually compensated in the voting process.

Random forest is also a method of bagging, but it has several features [10]: it uses an ensemble of only regression or classifying decision trees; in the sampling algorithm the random selection of features is also carried; the decision trees are built up to the full completion of the training objects and are not subjected to post pruning.

4 Research results

To build decision tree models, Python with libraries that implement machine learning methods was used [11]. Classification of time series obtained by generating stochastic binomial cascades with different multifractal properties was carried out. Each class was a set of model time series with the same Hurst exponent. Hurst exponent values were varied in the range of 0.5 to 1 in increments of 0.05. Thus, the training of models was carried out in 11 classes.

In the work, to determine the time series belonging to one of the 11 classes, the methods of bagging and random forest were used. In this case the objects were the cascade time series, and the features were the values of this series. In each of the methods, the ensembles of decision trees, both classifications and regressions, were involved. In the case of regression decision trees, the result of the classification is the probability of matching of multifractal cascade to given class. The models for each class were trained on five hundred examples of time series and were tested on fifty test ones.

The probabilities are calculated by the formula: $P_i = 1 - |m_i - C|$, where m_i is the regression result for the i-th example, C is theoretically known class number. If the condition $P_i \in [0.5;1]$ is met, the classification is considered as correct. If $P_i < 0.5$ and $m_i > C$ then the cluster number is overvalued, otherwise it is understated.

Table 1 presents the average probabilities of class determination depending on the length of time series and the method of classification. The results show that the use of regression trees gives significantly greater accuracy than classification trees. The random forest method showed better results than bagging. It should be noted that random forest correctly classifies cascades of different lengths, what allows it to be used to classify short time series.

Table 1. Average probability of class determination

Length of time series	Bagging classification	Bagging regression	Random forest classification	Random forest regression
512	0.646	0.788	0.806	0.85
1024	0.655	0.832	0.834	0.878
2048	0.676	0.882	0.842	0.916
4096	0.71	0.896	0.852	0.918
8192	0.748	0.9	0.866	0.922
16384	0.768	0.93	0.872	0.926

5 Conclusion

In this paper, the comparative analysis of the classification of model multifractal stochastic time series using meta-algorithms based on decision trees has been performed. Binomial multiplicative stochastic cascades were used as input time series.

Time series were divided into classes depending on their fractal properties. Random forest and bagging methods were used to classify the series. In each method, ensembles of decision trees, both of classification and regression, were involved.

From the research that has been carried it is possible to conclude that the classification of series by fractal properties using decision trees methods gives good results. The best results were obtained with the use of regression trees. In the classification of the series with a small length random forest method showed greater accuracy.

The obtained results can be used for practical applications related to the classification or clustering of real time series with fractal properties. In our future researches we intend to concentrate on the classification of real series using additional features such as fractal characteristics.

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Mobile Application to Determine the Severity of Salmonellosis Disease

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Abstract. The paper deals with studying the use of mobile devices for diagnosing in medicine, working out the element of medical students' electronic teaching and applying the mobile app in learning infectious diseases, namely, salmonellosis. The amount of people infected with this disease have been increasing year by year. The complexity of curing the moderate and serious diseases depends on the timeliness of determining the patient's condition. The authors have statistically researched how four indices of clinical blood test that affect the course of disease are significant. Three mean values of each of the four indices of clinical blood test were shown, which correspond to the three levels of severity of the disease. The application for mobile devices that enables the urgent and accurate determination of the salmonellosis disease severity without extra time and financial expenditures has been worked out. It can be used by students in the academic process, by doctors while rendering the first aid to patients, as well as for the independent disease course control by a patient himself / herself.

Keywords: Mobile App, Salmonellosis, Concordance Correlation Coefficient, Sign Test, Android, Kotlin.

1 Introduction

Today there are more than 325 thousand mHealth apps in the sphere of medicine. Most of them are free of charge. Research2Guidance prognosticates that the most prospective tendency of mHealth in the nearest 5 years will be elaboration of apps for distant monitoring and consulting [1]. In Ukraine the new edition of the technical regulation that is worked out according to the EU Medical Device Directive has been mandatory since July 1, 2015.

We have analyzed the modern state of incidence of salmonellosis, an intestinal infection, in the world. People all over the world suffer from this disease. About 94 million cases of salmonellosis are detected annually [2]. In the European countries where the incidence amounts to 23,4 cases per 100 thousand people the disease has a considerable influence on the population health [3]. The main task of curing the disease is early determination of its severity degree. This topic is studied by scientists all over the world [1-3], the patient's condition and products that cause the disease are analyzed, the formulae for clinical blood test are suggested, the statistical analysis of data about the disease at a particular period is conducted, but no source contains the reference to an app or calculator that is used by students or practitioners to urgently determine the degree of the disease severity. Such an app is especially topical while the ambulance service and rendering the first aid by family physicians are involved in the medical reform which starts on January 1, 2018. For the first time we have created the app for the Android which will help to quickly determine intoxication indices and disease severity without a personal computer and at any place. The app is basically aimed at the automatization of calculating intoxication indices to shorten time and determine the patient's condition more accurately. The basic requirements for the application are the possibility to put in data, to calculate intoxication indices and to determine the patient's condition, the modern design of the app, the convenient use.

2 The Basis for Mobile App Creation

Creating the mobile app has relied on the integrated development environment (IDE) for the platform Android – Android Studio. This program is free of charge, it is licensed by Apache 2.0. Android Studio is based on IntelliJ IDEA Community Edition that is supported by the company JetBrains. The applications for the operation system Android can be made in many programming languages [4-6]. The most popular language to develop on the platform Android is Java now [5]. But while creating the application we have used the programming language Kotlin [6]. The use of the programming language has been determined by the fact that it is the most modern and the easiest one to write programs. Kotlin can be compiled in two variations: bytecode JVM and JavaScript. All the Java-frameworks and libraries can be also used. Kotlin may be converted into Java and just the other way round. This programming language is null-safe. The important advantages of Android Studio are the represented collection of typical interface elements and the visual editor for their combination that provides the convenient preview of the targeted application, code highlighting, analysis and detection of errors, integration with the control system.

3 Statistic Preparation of Data to Create the App

It should be noted that the salmonellosis disease falls into three degrees of the clinical course. The criteria for the degree of salmonellosis severity comprise the height of fever and its duration, stool frequency and volume and duration of diarrhea.

The mild severity degree is characterized with low grade fever, watery stool up to 5 times a day, duration of diarrhea for 1-3 days. The temperature of 38-39° C for 4 days and the stool up to 10 times a day for about a week indicate the moderate degree of severity. The evident intoxication, the temperature that rises to 39° C and higher for five or even more days and profuse stool more than 10 times with the duration for more than a week are characteristic of the serious degree of severity.In order that the severity of the gastrointestinal salmonellosis should be accurately diagnosed, we have used for the first time the integrative indicators of endogenous intoxication the determination of which does not involve extra expenditures, apart from the conventional analyses – clinical blood test [7]. It has been found out what indices reflect the degree of disease severity most objectively. For this purpose, the concordance correlation criterion has been applied: we have dealt with the most widespread variants to determine the sequence of the importance of indices investigated in case records to evaluate the hypotheses of different levels of importance of four indices: the index of shift of leucocytes (ISL), the leucocytic intoxication index (LII), hematological index of intoxication (HII), the index of intoxication (II). Their analysis has presupposed the ranking number for every index.We have used the concordance correlation coefficient for the case of tied ranks (the same values of ranks in evaluation of the same hypothesis).

$$W = S / (\frac{1}{12} m^2 (n^3 - n) - m \sum_{i=1}^{m} T_i), \; T_i = \frac{1}{12} \sum_{i=1}^{l_i} (t_i^3 - t_i),$$

where S - the sum of ranks, m - the number of hypotheses, n - the number of indices, T_i – the number of connections (types of the repeated elements) in evaluations of the i^{th} hypothesis, t_i – the number of elements in the l^{th} connection for the i^{th} hypothesis (the number of repeated elements). Then we have set the task to find out what indices influence the accurate diagnosis. As a result of the research, it has been identified on the basis of expert rating that the most significant qualitative properties are ISL and LII [7].

4 Key Moments in Creating the Application

Then, based on the results obtained, a mobile application was created to quickly determine the severity of the disease for salmonellosis, which can be found by reference http://play.google.com/store/apps/details?ld=com.kam123.ua

The application for the operating system Android is a set of classes and forms. Every form is an object of the class Activity, the interconnection between them is realized by the object of the class Intent.The first form is for data input by the user. The main designated purpose of the first form is getting the necessary information from the user. The user puts in the data about the clinical blood test that are necessary to determine the severity of salmonellosis disease. The second one reflects the general theoretical data about each intoxication index. The third form demonstrates the results of calculations and the information about the obtained degree of disease severity. The object of the class Intent is employed to change the form. The additional elements EditText are essential for data input, and the button “Calculate” initiates the call of another form and puts down the results of calculations into static variables in the class Result. After that the results are available in the form in which the answer is output. The variables that have the static modifier are global variables. When the class objects are initialized the copies of a static variable are not made. All the samples of the class make common use of one static variable. It is not necessary to create an object of the class to get access to the static variable. The event processor is not obligatory to simulate pressing the button. The attribute OnClick specially elaborated for Android has been used. It is the modern approach to programming on Android that makes the elaboration easier and shortens the number of lines in the code. The class Formula has been created for calculations. It stores static functions which compute intoxication indices and determine the disease severity. It allows to apply formulae from any part of the program.

The calculations are made in the following way:

val LII_v = Formula.LII(M, Y, St, Se, Pl, Ly, Mo, E)
val HPI_v = Formula.HII(LII_v, Cesr, Cl)
val ISL_v = Formula.ISL (E, B, St + Se, Mo, Ly)
val II_v = Formula.II(LII_v, Lc, ESR)
val res = Formula.result(LII_v, HPI_v, ISL_v, PI_v, T, K)

The results are written into global variables of the class Result. Then the form with the results opens by means of the method startActivity:**val** intent = Intent(**this**, ResultActivity::**class**.*java*)startActivity(intent). Then we turn to variables of the class Result which are output on the form Result Activity. To start working with the application one should put in correct data and press the button "Calculate". After pressing the button "Calculate" the check is carried out whether all the columns are filled in. If one of the columns is not filled in, the warning will appear, and they will be filled in with zeros. After all the data are put in the program computes the result.

Appendix

For the first time the mathematical model of calculating the degree of gastrointestinal salmonellosis severity has been elaborated. The application for the urgent and accurate determination of the disease severity degree has been created that can be used by medical students in studying, by medical staff for making a diagnosis and rendering the emergency care, infection disease doctors at different stages of patients' treatment and, finally, in the independent disease course control by a patient himself / herself. The severity of salmonellosis disease is determined quickly and without economic expenditures, besides objective indicators are additionally regarded.

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Developing of Key Competencies by Means of Augmented Reality in Science and Language Integrated Learning

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Abstract. Using of new learning and IC technologies is necessary for effective learning of modern students. That is why it can be reasonable to introduce augmented reality and content-language integrated learning in educational process. Augmented reality helps create firm links between real and virtual objects. Content and language integrated learning provides immersion in an additional language and creates challenging group and personal tasks in language and non-language subjects. Using these technologies in complex provides social and ICT mobility and creates positive conditions for developing 9 of 10 key competencies. The paper deals with the features, problems and benefits of these technologies' implementation in secondary schools.

Keywords: Augmented Reality, Science Learning, Key Competencies, Generation Z, Content and Language Integrated Learning (CLIL).

1 Introduction

Current secondary school students are members of "Generation Z" cohort (according to Strauss and Howe). ICTs and social media are the essential parts of "Zeds" world. So using ICTs in education is not an option but a necessity. The most helpful educational technologies for "Zeds" are smartboards, digital textbooks, websites, online videos and game-based learning systems. [1, pp. 6-8]. That is why we have to create dynamic learning environment, which contains modern ICTs as its inseparable part.

2 Using Augmented Reality in Science Learning

Jean-Marc Cieutat, Olivier Hugues and Nehla Ghouaiel define AR as the combination of physical spaces with digital spaces in semantically linked contexts for which the objects of associations lie in the real world [2, p. 32]. According to Gartner hype cycle analysis AR is a mature technology [3] and is going to be widely used in different spheres of our lives (including education).

The main benefits of using AR are connected with studying objects and phenomena, which are inaccessible for direct cognition, but can be observed by means of AR. It can be very useful in learning abstract Math and Science concepts. AR shows the links between real and virtual objects. Moreover, AR can be a good example of developing technology by itself. At schools AR can form some “digital” habits which can be useful in future life. Using AR in a classroom makes it possible to learn in a personal-oriented environment. It helps students to provide their own learning styles. According to The State Standard of the Basic and Complete Secondary Education there are 10 key competencies [4]. The benefits of using AR in secondary schools are given in the Table 1.

Table 1. Advantages of using AR at science lessons (in regard to key competencies).

Competency	**Component of Competency**			
	Cognitive	**Skills and Experience**	**Values**	**Social and Behavioral**
Mathematical Competency	supporting of abstract mathematical concepts learning	scaffolding of basic math skills (i. e. geometry imagination)	giving an example how maths equations come to life	making better conditions to provide own learning style
Competencies in Science	supporting of abstract concepts learning; improving links between nature objects and phenomena	making possible to operate with objects, which are inaccessible for direct cognition	demonstrating science implementations; motivating for science learning	making better conditions to provide own learning style
Digital Competency	widening outlook; getting knowledge about AR	mastering subjectively new technologies	demonstrating the importance of digital literacy	mastering new ways of digital learning communication
Lifelong Learning	demonstrating infinite technological progress	getting new learning habits	demonstrating entertaining and useful learning potential	mastering new ways of learning communication
Sense of Initiative and Entrepreneurship	gaining knowledge about effective ways of organizing information	getting experience of applying the same technology in different fields	helping to adapt to constantly changing situations (using an example of AR)	mastering new effective ways of communication
Cultural Awareness	mastering new effective ways of gaining cultural knowledge	improving praxeological component of technical awareness	making cross-cultural links more obvious	giving opportunities for creating own style of self-development
Ecological Competencies and Health Care	helping to understand the complexity of ecological and medicine processes	acquiring skills and getting experience of health care by themselves	helping to understand links between nature phenomena and human activities	making better conditions for creation of own health care programme

The most essential drawbacks of using AR are connected with deficient studies of its influence on user's health and a lack of privacy and security [5]. We should say that the last problem is mainly caused by irresponsible using of AR; it is not AR itself. That is why it is especially important to teach students basics of AR using (including safety regulations). One of the difficulties, which we face applying AR at Ukrainian secondary school, is their English interface. We can overcome this drawback by developing foreign language competency.

3 CLIL Approach In Education

Content and Language Integrated Learning (CLIL) is a modern approach to the developing of foreign language competency [6]. CLIL is a dual-focused educational approach in which an additional language is used for the learning and teaching of content and language with the objective of promoting both content and language mastery to pre-defined levels [6, pp. 2, 65]. Advantages of CLIL approach (in regard to key competencies [4]) are reflected in the table 2.

Table 2. Advantages of CLIL science lessons approach in key competencies forming.

Competency	Component of Competency			
	Cognitive	**Skills and Experience**	**Values**	**Social and Behavioral**
Foreign Language Competency	cross-subject vocabulary	real learning situations; providing more language practice	wider access to science sources; using languages for practice	mutual assistance in learning; more accessible social environment
Mathematical Competency	learning specific terms in a foreign language	learning culture-based math rules (e.g. mnemonics)	realizing the impact of math on learning mobility	empowering social interaction in learning math
Competencies in Science	a variety of learning objects and sources; learning terms in English	learning culture-based science rules (e. g. mnemonics)	understanding the importance of science for learning mobility	empowering social interaction in learning science
Lifelong Learning	cross-subject links; opportunities to work with various resources	acquiring skills of "mining" knowledge in different languages	increasing awareness in different branches of learning	forming collaboration habits in learning English and science
Social and Civic Competencies	developing better cross-cultural understanding	shaping tolerance and respect to other cultures	showing an impact of all cultures on science	broadening social experience
Sense of Initiative and Entrepreneurship	providing a wider range of resources	broadening teamwork experience	showing the personal input in common success	mutual assistance in learning English and science
Cultural Awareness	widening outlook	widening a range of multilinguistic activities	revealing the value of different knowledge areas	enhancing ability to reflect cultural diversity

The backgrounds of CLIL lessons are: proper level of students' language skills, parents' and students' demands for social mobility, the teachers' readiness to introduce CLIL lessons and social competency of all educational process participants. Introducing CLIL lessons faces such difficulties as curriculum coordination, consuming a lot of time to prepare a CLIL lesson and a lack of appropriate resources. Taking into consideration both recent researches [6] and our practical experience we can conclude that CLIL lessons are more interesting, motivating, time-saving, help students to feel confident, promote communication, provide educational diversity and increase mobility.

4 Conclusions

Nowadays new learning and IC technologies are required to satisfy "Zeds" demands. For instance, all reviewed technologies provide individual learning strategies. The using of both AR and CLIL helps to form and develop 9 of 10 key competencies (except native language competency). Augmented reality helps to create the firm links between real and virtual objects. Content and language integrated learning creates conditions for efficient group and individual work in language and science learning.

Implementation of these technologies is reasonable only under certain conditions: gadgets and appropriate level of teachers' digital literacy (for AR) and the proper level of foreign language competency (for CLIL). The main difficulties, we face applying these technologies in science learning, are connected with organization of educational process not with teaching or learning. AR and CLIL technologies together create rich learning and teaching environment for effective education of modern students.

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Computer Models as a Means of Teaching Physics in Higher Educational Institutions

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Abstract. The article is devoted to the development and application of computer models in a course of laboratory works in physics. The paper contains the results of pedagogical experiment which aim was to develop student's skills to process the result of experiment.

Keywords: general physics, computer model, physics practical works, higher educational institution

1 Introduction

The problem of using computer models of physical phenomena is relevant in our time. Computer models allow students to observe the course of the physical process and its results while being outside the physical laboratory.

The researchers have substantiated the basic principles and methods of teaching students the modeling of physical phenomena (M.V. Dudyk, S.A. Khazina [1]), the choice of software tools for the creation of computer models of physical phenomena (S.O. Semerikov, I.O. Teplitsky [2]), was developed Computer models of physical phenomena (employees of the University of Colorado Boulder [3]), the requirements for training programs - computer models of physical processes (V.M.Bazurin [4]) have been substantiated, the peculiarities of the development of computer models and their application in teaching (Y. Xu, J. Choi [5], R. Alcarria, B. B. Sanchez, A. Sanchez-Picot, D. Sanchez-de-Rivera [6]).

Our study aims to determine the impact of a virtual laboratory experiment on the formation of research skills of students of non-physical specialties, namely the ability to process the results of an experiment. For this purpose, computer models of such experiments were developed: determination of resistivity of the conductor (OhmLaw), determination of the internal resistance of the current source (IntResistance), capacitor capacitance measurement by means of a ballistic galvanometer (Condensator), determination of conductor resistance using the Wheatstone bridge (WheatstoneBridge), research the laws of electrolysis (Electrolysis), the determination of the heat capacity of the solid (Teplo), the determination of the temperature linear expansion coefficient of the metals (Linear), and others.

In the experimental group there were 22 students, in the control group - 14 students.

The criterion for the development of research skills is the number of correctly performed calculations of the results of a laboratory experiment. Criterion Indicators: 0-4 - low level; 5-8 - middle level; 9-12 - high level.

Hypothesis: conducting a laboratory practice in physics on virtual computer models for students helps to develop the students' ability to perform processing of the results of a physical experiment.

2 Main Ideas

A laboratory workshop on physics can be implemented in two main forms: traditional (research on laboratory equipment); virtual (research on computer models).

Research in laboratory conditions has the following disadvantages: the need to have sufficient modern equipment; moral and physical obsolete equipment; high price of equipment; the inability to reproduce certain experiments in real conditions due to their harmfulness [7].

To implement a virtual laboratory experiment requires the availability of computer models of physical phenomena. Computer models need to be developed specially.

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3 Description of Materials and Methods

Laboratory Physics Workshop consisted of 12 works. In experimental groups, classes were conducted using developed computer models.

For example, using the OhmLaw program (fig.1), students first determined the resistance of the conductor (by the Ohm’s law). The length and diameter of the conductor were specified by the program. After determining the resistance students at the known values of the length and diameter of the conductor calculated the area of the cross-section, and then - the specific resistance of the conductor. Students entered the results of the experiment in the corresponding text fields of the program, after which the program performed a check of the correctness of the calculations.

In the control group, a laboratory workshop was conducted on laboratory equipment.

For each student, the number of correctly performed calculations was calculated based on the results of the laboratory experiment.

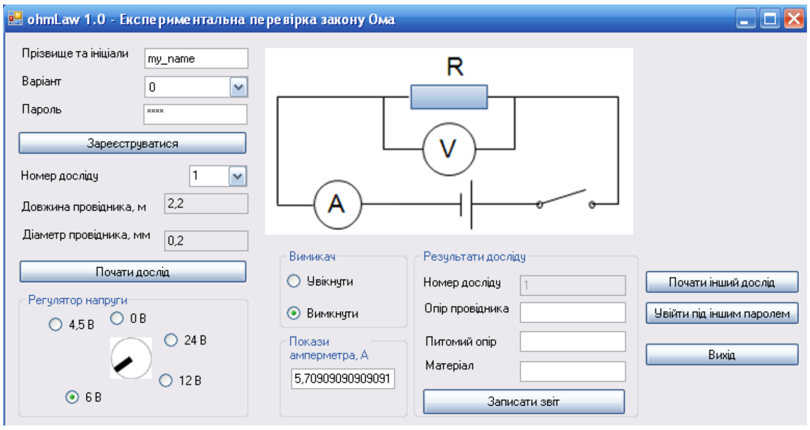

Fig. 1.

The results of the experimental study for the experimental and control group were compared using the Whitley Mann criterion.

4 Results

The level of formation of the ability to process the results of the experiment for students of control and experimental groups is shown in Fig.2.

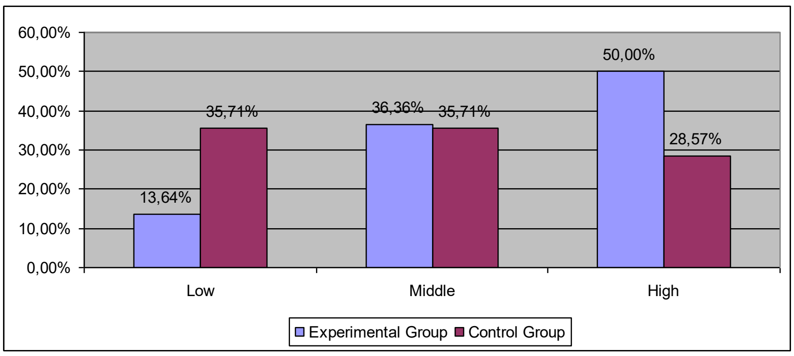

Fig. 2.

5 Discussion

The obtained data are important for the formation of the students' skills to process the results of the experiment. Subsequently, these skills will be used by students when studying disciplines such as material resistance, technical mechanics, theory of machines and mechanisms, as well as when writing bachelor's and master's theses.

Perspective directions of research are:

- development of web-oriented computer models that store the results of work in the database;
- definition of the optimal type of interface of computer models;
- determination of optimal program structure - computer model;
- construction of a laboratory workshop on computer models as a holistic system, development of software for distance learning and home laboratory experiment.

6 Conclusions

1. Laboratory workshop with using computer models of physical processes facilitates the formation of such an important component of research skills among students as the ability to process research results;
2. Development of computer models of physical phenomena has wide prospects for their application in the process of studying physics in higher education institutions.

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Usage of Self Created Mind Map Environment in Education and Software Industry

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Abstract. The report describes the use of mind maps as a modern tool of learning and teaching. It describes possibilities of using mindmapping for teachers in classical universities or mentors and developers in IT-companies for presenting new material, developing a course or evaluating developers' understanding, as well as for developers studying a specific subject, preparing for examinations and high-quality memorization of information. Authors designed and developed their own new software solution for easy creating and editing and sharing mind maps with an intuitive user interface and efficient abilities. The report contains description of implementation of mind maps usage in software development during training of students in Chernivtsi National University and software engineers in IT-company SoftServe. The process of developing new one-page application for creating mind maps using the React library in the JavaScript language is being described.

Keywords. mind maps, online environment, modern learning methods, web-technologies in mentoring.

1 Development New Web Environment for Mind Maps Creating

Educational facilities have access to world information resources, new means and methods of teaching and learning with scientific and educational systems have emerged [1]. The educational process as information exchange includes processes of visualization, transfer, preservation, and processing of information [2, 3]. The visual communication is the most natural way of human interaction. In education, the importance of visual communication is the most obvious, as its methods carry out the management of the educational process when students use resources for independent learning. Mind mapping is a technique of thought visualization that helps to express and perceive information in better and more effective way [4].

This paper contains an overview of a process of development of client web application, which can be used to display, build and edit mind maps. The available tools and approaches to the development of web applications such as platform, architecture, frameworks and libraries were analyzed. In a process of research, there were created a list of functional requirements for **MVP** and they were implemented.

Developed software allows users easily create and edit mind maps, has the ability to export **PNG** images and an intuitive user interface created using a component approach and combining components from user-defined packages and componets developed by the author. The list of functional requirements for the application was compiled, and software code that satisfies them was developed.

For development, the text editor of the code **VS Code** was used, with some extensions for ease development. **Git** was used as a version control system, the program code is located in an open repository on the **GitHub** service.

1.1 Analysis and Selection of Tools for Implementation of the Application

As a platform for the application was chosen **web platform**, because it does not require additional installation and it is universal for all devices: personal computer, laptop, tablet, mobile phone, and does not depend on the installed operating system.

When choosing the application architecture, preference was given to **client-server architecture** and client application development, although the option of server-side development for **MVC**-based relationship was also considered. Client applications are separate applications with their own code-base and usually interact with the server using **HTTP** queries. Server applications process requests and return an **HTTP** response, usually with a body in the **JSON** format.

Since the end product is a web application, then the obvious choice of programming language is JavaScript. For development **ES6** standard approved in 2015, has been used.

When choosing a framework, the preference is given to **React** because it does not have an **MVC** on its own. **React** is a declarative, productive and flexible **JS** library for developing user interfaces. One of the key features of **React** is the use of **JSX** syntax, an extension of the **JS** syntax with **HTML** tags.

Semantic **UI React** was used to stylize the user interface. It contains a **Semantic UI** style library and integrates with **React**. Mind maps have a tree structure and, accordingly, are objects for display by libraries that build trees and graphs, so for implementation was selected **Cytoscape.js** – a library for analyzing and visualizing graphs [5].

1.2 Functional Requirements

The list of functional requirements for an **MVP** software product was developed. **MVP** describes the minimum viable product with a set of capabilities that is sufficient for effective usage.

Free open source crossover editor **VS Code** was used as development environment. **VS Code** has built-in support for a distributed version control system **Git** and convenient features for debugging software code. The editor has built-in support for **JS** and its dialects, including **ES6** and **JSX**. To create the skeleton of the project, the **Create-react-app** tool was used. It contains most of the mechanisms necessary for the development of tools, such as a local static server, auto prefixers for **CSS** files, scripts to run a project assembly, and built-in support for the **Webpack** collection.

The installation of libraries for the project was handled with **NPM,** the package manager for **JS**. In addition to the **Create-react-app** packages installed during the project initialization, **Cytoscape.js**, **Semantic UI React**, and some others are added to the **package.json** configuration file. All listed packages can be found in the **NPM** registry.

1.3 Implementation of the Application

React-router was used for configuration routing. It provides navigation component package for declarative routing description.

Using **Cytoscape.js** library, the initial mind map was created. It displays when user opens the application. It contains descriptive information about the features and abilities of the application.

To give the user the opportunity to conveniently and efficiently editing of mind map, a context menu was created. It is placed directly above the active element. The context menu allows use to create new node, edit information in the current node, add a picture to the node and delete current node.

Before the application release user interface was improved with new features: colourized connections between primary and secondary map elements, linear edges were replaced with more appealing **Bezier curves**. To implement edge thinning depending on a distance from map root it can be used a recursive tree traversal algorithm, but because acyclic map support can be implemented in future releases we used **Belman-Ford algorithm**, which is built-in in **Cytoscape.js**. The algorithm computes shortest paths from a root node to all other elements. Then the edge width is calculated as an inversely proportional value to the distance from the main node.

1.4 Application Release and Usability Overview

The deployed application is accessible over the internet. A built-in bundler from create-react-app was used for the release version.

The developed application is essentially a web-client, therefore, it only needs a static server to be deployed. For this purpose, we used a free static hosting on **Github** platform, where the application codebase is situated. To reduce the amount of manual work the process of deployment was automated. To do so we used gh-pages library, that runs build command and automatically copies build results into a separate git branch "gh-pages". **GitHub** then automatically updates the static server with new releases that are pushed into "**gh-pages**" branch. The application is accessed through a link hosted on **GitHub** domain: https://makalkin.github.io/mindblown/.

By launching the application on a local server or by using live version one can start making mind maps by following initial instructions.

2 Recommendations for Future Improvements

Firstly, it is worth to create automated tests for the developed application to prevent regression. This can be done with a help of frameworks that serve just this purpose like **Mocha**, **Jasmine** or **Jest**. It is important to take into the account compatibility of frameworks and technologies used in the application and a testing framework.

An important aspect of application improvement is the ability to automatically place elements in all directions from the main node and support of acyclicity. A custom extension for **Cytoscape.js** can be implemented to achieve the former.

To make application collaborative it needs functionality for cooperative editing of a mind map and cloud saving. This can be implemented with cloud services like **Firebase** or similar, which do not require user to own a dedicated server, and so collaboration can be achieved with help of event streams and web-sockets.

For simplicity, the color of main branches is generated randomly and inherited by all its descendants. There is always room for optimisation and other functional improvements of software. The feedback and expectations of the target audience are valuable pieces of information that should be used to set priorities. So before further improvements, we need to collect statistics, analytics, and user feedback.

The advantage of the application is its simplicity and minimalistic **UI**, which turns all available space except browser header into a canvas. One can use a fullscreen feature of a browser for full immersion. There's also no registration required prior to using the application.

As a drawback, the application is dependent on **Cytoscape.js**. It has helped us to implement features fast with help of its built-in methods but at the same time, it made the application limited, because it relies on a support of the library by its developers. For future releases, it is recommended to implement extensions for the library or implement a standalone library, but that is quite time-consuming and demanding task.

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Development of the Ateb-Gabor Filtration Method in Biometric Protection Systems

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Abstract. The Gabor filter for biometric images has been investigated. Introduced a new Ateb-Gabor filter to improve the quality of fingerprint images. The sequence of filtration and recognition of biometric data is developed. For reliable fingerprint recognition, image correction is required, since interference caused by scanning may distort the lines of the imprints, which creates errors in recognition. The mathematical apparatus of the Ateb-functions provides additional functions for controlling Gabor's filtration, since it has a wider range of filtering options. It has been shown that the use of the Ateb-Gabor filter has a more controlling influence on the image, because in addition there are two parameters of rational numbers that considerably extends the filtration process.
The method of filtering images based on the Gabor filter using Ateb-functions is developed. At present, work is being done on the application of a new filter to biometric images, bringing it to a finished software product. A two-dimensional Gabor filter is also developed, which in the future will allow people to recognize faces.

Keywords: Ateb-Gabor; Gabor Filter; Image processing.

1 Introduction

With the development of information technology, biometrics has become an essential part of our everyday lives. Biometric identification systems require constant improvement since they work fairly slowly and often give the wrong results. new methods have been developed for fingerprint analysis, which scans them without any contact [1]. Similarly, the scanning and recognition technologies in 3D space appeared [2]. As a result, professional systems for recognition were developed [3]. Using the technology of the "large data" processing, modern surveillance systems and access control systems identify individual fragments of biometrics more accurately, and technologies for identifying specific people in the stream are developed [4].

2 Gabor Filters and Image Processing

One of the most popular methods for selecting the edges in the image is the use of Gabor filters [5]. The real part of the nucleus of the Gabor filter are constructed using [6]. To construct an imaginary part of the Gabor filter, it is necessary to replace the cosine function with the sine calculation in the above formula.

3 Filtration

The filtration process involves the convolution of the filter and the input signal in the spatial domain. In this paper, it was done in the Wolfram Mathematica 11 computing environment [7]. Multiplication in the spatial domain is equivalent to convolution in the frequency domain [8].

$$r = image * filter \tag{3}$$

where r - is the result of filtration; * - convolution and $filter$ - Fourier transform of the Gabor filter. The Fourier transform of the Gabor filter is a Gaussian signal [8], whose center is located at the center frequency of the filter. As a result of multiplication in the frequency domain, the amplitude of the output frequency close to the sinusoidal signal increases, while others decreases.

3.1 Implementation of the Gabor filter

The width and height of the filter are determined by the width and height of the Gaussian component. Determining the correct width and height for the Gabor filter is essential while designing new filters. Experimentally established [9] that a good filter, capable of detecting narrow edges at a certain frequency should have boundaries in the plane z = 0 and also it should have two negative and one positive peak.

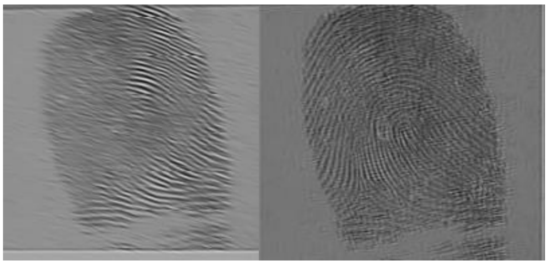
3.2 Generalized One-Dimensional Ateb-Gabor Filter

We construct a generalized one-dimensional Gabor filter basing on the Ateb-functions [10]. It will look like:

$$g(m,n,\omega) = e^{-\frac{\omega^2}{2\sigma^2}} \mathrm{ca}\left(m, n, 2\Pi, \theta, \omega\right),$$

where σ - is the standard deviation of the Gaussian nucleus, which determines the amplitude of the function, ω - is the frequency of oscillations, which is defined as $\omega = 1/T$, де $\mathrm{T}(m, n)$ – is the period of Ateb function $\mathrm{ca}\left(m, n, 2\Pi, \theta, \omega\right)$, 2Π – period of Ateb-function.

The experimental results of the filtration are shown in the figure below. In fig.1 a is filtered by an ordinary Gabor filter, and fig.1 b filter is Ateb-Gabor with m=n=3 with the best results of filtration.



a b

Fig.1. Filtration a) ordinary Gabor filter b) Ateb-Gabor filter with m=n=3

The optimal correlation between frequency and width of the Gabor filter has been determined, which allowed performing filters automatically with the purpose of finding the edges of objects with different frequencies, sizes and directions. The optimal correlation is in each specific image of its own. The method of removing the average component of the Gabor filter is proposed, which allows reducing the value of the average filter to zero without deforming the filter. The results of numerous experiments demonstrate the successful selection of edges in the image based on the results obtained in the work of the Gabor filter parameters.

4 Image Processing Using the Gabor Filter

In each fingerprint, you can identify two types of attributes - global and local. Global signs are those that are visible to the naked eye. Another type of attributes is local.

They are selected because lines of the fingerprints are not straight. These points provide unique fingerprint information in the process of identifying a person. Each printout contains up to 70 minutia points [10].

The implementation of the Gabor filter for images takes place in five steps.

Step1. Image normalization. Normalization of the image is necessary in order to set the previous mean values and deviations.

Step2. Calculation of the orientation. The orientation image *Img* represents the matrix $N \times N$, in which each component *Img* (i, j) shows the local orientation, angle of inclination at a given point of the line with coordinates (i, j).

Step 3. Calculation of the frequency image. The frequency image is a matrix of size $N \times N$, in which each component *Img* (i, j) shows the local frequency of the lines at a given point, which is defined as the frequency of the crests directed along the orientation of the protrusion. On the next step, the skeletelization of the image is based on the wave method [11].

Step4. Binarization of the image.

Step 5. Apply to the binary image of the Gabor filter. The filter is configured for the local orientation of the speeches, applied to the pixels of the projections and vices of the image.

5 Conclusions

The Gabor filter for biometric images has been developed. A new filter of Ateb-Gabor has been investigated and its efficiency in application to biometrics has been proved. Work is carried out to filter images and study their characteristics based on one-dimensional and two-dimensional Gabor filter. We think that we will achieve significant results in the near future. The use of a generalized Gabor filter will allow for better filtration and have a large number of parameters to choose from for the best filtering options. The change of the parameters m and n provides different values of the period, which makes it possible to expand the number of filter options. To solve the problem of fingerprint identification, the Ateb-Gabor function allows you to improve identification, and, based on it, filtration of images with a large number of ridges. This provides better characteristics than the usual one-dimensional Gabor filter.

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Tripled Learning: Conception and First Steps

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Abstract. In the article, the concept of tripled learning is considered. There are provided advantages of tripled learning and first results. We ty to combine the blended learning with team work for the first year students of specialty "Computer sciences".

Keywords: tripled learning, education process, team work.

1 Introduction

Recently, there is a tendency for students to lose interest in research and learning in general. The main reason for this development is lack of motivation. Students do not have the opportunity to concentrate on their studies, they more like games or research [1]. Thanks to the rapid development of information technology, people do not have the time or the desire to read books, record lectures and perform traditional laboratory work. First of all, this applies to students from areas related to information technology. The scope of IT is innovative, and it is natural that traditional teaching methods such as lectures and books are not always effective. It is very important to encourage such students to study and research. For this purpose, it is necessary to update the traditional system, making it more interesting and relevant.

2 The Tripled Learning Approach

Nowadays the learning process have different implementations. Next to traditional or "classic" methods [2] such as lectures and practical works there is also its online version as e-learning and their combination - blended learning [3]. Also the gamification of learning process is popular [9].

Our proposal is a new kind of learning – **tripled learning**. This is combination of three different approaches:

1. Offline or "classic" learning process with lectures, individual practical tasks and individual laboratories.
2. Online learning at one or more preselected MOOC according to main case of studies.
3. Teamwork on own projects.

All three cases are strongly connected and passed inside time framework. The final mark: 35% exam, 10% practical tasks, 20% laboratories, 10% success online learning, 25% project. Finally, students must show their results in three forms to:

1. Examination with dialog of lecturer.
2. Set of passed tasks with revised reports.
3. Public presentations of projects with grade from third part persons.

According to the proposed structure of tripled learning we expect the growth of learning and creative work efficiency. The conception of tripled learning made first steps in real teaching process at university.

During last months we made successfully implementation of proposed tripled learning into real learning process within course “Algorithmic and Programming. Part One” for the first year students of specialty “Computer sciences at the department “AI Systems”. This course created around the learning of procedural programming using C language with examples of using different algorithms and basic overview of operating systems like Linux, GitHub, networking, Internet, client-server technologies, modern web development, project management process and different up to date IT conceptions such as Cloud computing, Internet of Things, Artificial Intelligence, Robotics etc. with several practical applications. To cover the whole list of topics, 25 lectures with additional visualization and a detailed extended text description were developed. In this case, the main emphasis and most of the time is devoted to the study of programming using C language in various aspects.

By creating a training program by a group of experts, a number of different MOOCs were analyzed for the best possible compliance with the requirements of this course. As a result, the online course "Introduction to Computer Science. CS50" [4,5] from Harvard university as the main MOOC and "Design Thinking for Innovation" [6] from Darden School of Business, University of Virginia as an auxiliary for creativity training during the development of team projects was selected.

The next step was to develop a set of practical tasks for work in computer laboratories that would be coordinated, supplemented, and expanded the corresponding tasks from “CS50”. As a result, detailed step-by-step guidelines were developed for 15 practical programming works in accordance with the length of the academic semester at the university, which were in harmony with the tasks from “CS50”.

A separate task was to organize teamwork on various projects during the semester. As a result, from all 124 first-year students, 32 original authoring projects with a team size of up to 5-6 people were formed. The results of the projects were successfully presented to the jury from the invited top managers of various IT companies. The subject of the completed projects was very diverse, namely:

- Applied tasks of AI, computer vision and neuro networks;
- Augmented Reality (AR) applications;
- Different Internet of Things (IoT) prototypes using Arduino and elementary AI;
- Robotics tasks using original author’s platform T-Bot;
- Mobile applications;
- 3D learning games;

• Web sites and web applications.

All the results of the **tripled learning** process were reflected on a dedicated web site named “AI Students” created by our students. It contains a list of all projects with their presentations, videos and links for downloading whenever possible. On a separate web page there is a list of all students with their Certificates from Harvard University and University of Virginia on the successful completion on the relevant MOOC and links on their team projects. A fragment of the project description site is shown in Fig. 1 (http://ai.lpnu.ua/).

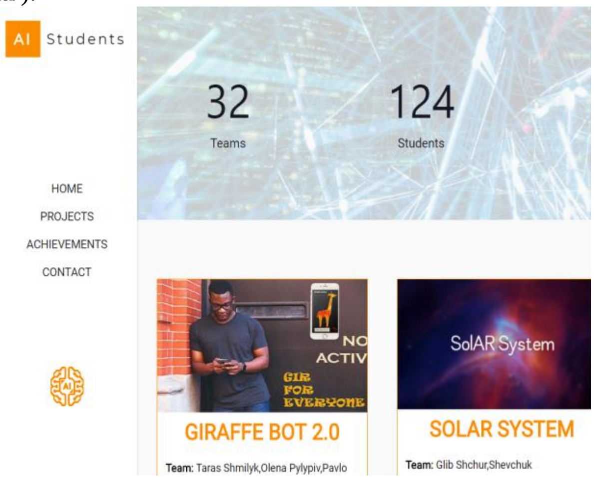

Fig. 1. Part of web site with results of the first implementation of tripled learning

For the robotics projects, a specially designed educational T-Bot platform was created. The created T-Bot robot consists of an Arduino board, motor shild, an ultrasonic range-finder, color sensors to follow along the route, two motors with wheels and position sensors and a gyroscope. The Arduino platform was chosen for next reasons:

1. Programming language is very similar to ANSI C.
2. Easy study with a low entry threshold.
3. Availability and prevalence of all components.

For tasks like tracking along the route, searching for an exit and avoiding obstacles, a specialized simulator was created. The T-Bots robots in a real project are shown in Fig. 2.

To ensure even higher quality of the learning process, it is advisable to use within tripled learning a specialized web-oriented e-learning system of third generation with the ability to remotely communicate using telepresence robot and specialized visual programming language as described in [7,8]. Especially promising is the using AI capabilities for personalized of learning process with permanent feedback and the next-generation of T-Bots robots with auto-balancing, but this goes beyond the scope of this article.

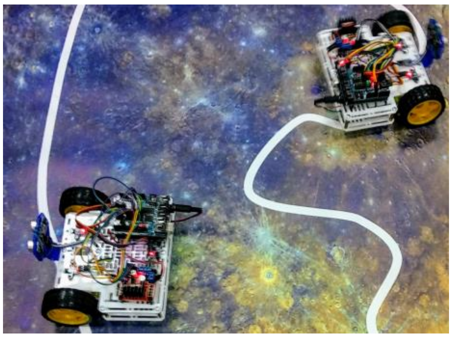

Fig. 2. Robots T-Bots during presentation of the one of projects.

3 Conclusions

Thanks to the proposed approach of tripled learning, the students not only studied the traditional university course but also attended distance learning at other universities, learned to use the benefits of MOOC, received the Certificates of origin and mastered teamwork skills with public presentation of their achievements.

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Recommendations Based on Visual Content

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Abstract. There is a large number of algorithms to perform recommendations for customers of online platforms. All depends on the data sources we have. Widely used approaches are based on transactional data and "ratings" matrices. For such kind of products as clothes, furniture, hand clocks it is very important to take into account not only some metadata characteristics, but also their "visual look". People always buy clothes based not only on their size, sleeves lengths, textile type, etc., but based on how it looks in general. In this poster paper, we will show how feature vectors of visual content could be extracted and used to enhance recommendations.

Keywords: Visual Recommendations, Deep Neural Networks, ResNet50, Deep features representation, fine-tuning of NN.

1 Introduction

In today's world, there are multiple ways to perform recommendations starting from using attributes and metadata of the products and ending with rates, received by multiple users. In this paper, we are proposing to include into recommendations also visual information, which could be extracted from photos of the products.

Visual information is stored in pixel values of the images. But exact pixels' representation is not the best way to represent images' features. These values are shifted towards position of the object on the image, lighting, etc. It is better to use some "deeper" representation, which could be extracted using neural networks.

2 Neural Networks for Deep Features Extraction

The best way to extract features of images is to use some neural network, which uses these features to perform classification. Earlier layers of such networks give us an opportunity to represent images in the best possible way for comparison with nearest neighbors.

Fine-tuning [3] is a frequently used approach while training neural networks with images. The main idea is to use already trained model and only slightly tune it to work with new data of the same nature. This approach is very useful while working with limited number of data. For example, to train image classifier from scratch we need tens of thousands of observations per class and days of training to achieve high accuracy. In case of fine-tuning it will be enough to have just few hundreds of images per class and a model could be trained in just a few minutes. This could be achieved by using pretrained deep features and building even linear classifier on top of them.

To create a model, subset of DeepFashion[2] dataset was used (46,985 images) to train 46-classes classifier (shirt, cutoff, jeans, suit, etc.). Subset of it could be seen on Fig.1.

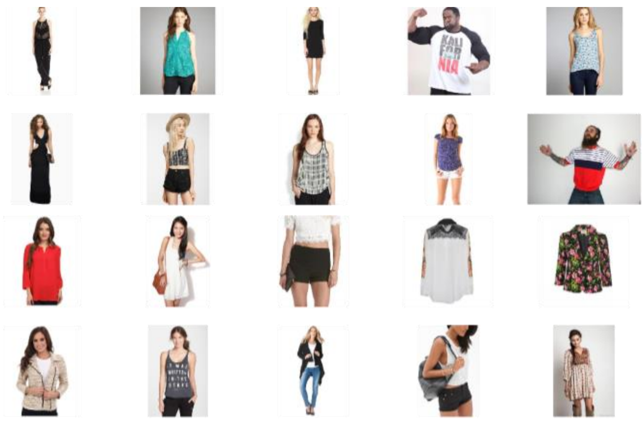

Fig. 1. Sample of DeepFashion dataset

To do fine-tuning, some base model is needed. For that purpose we have used ResNet5[1] trained on ImageNet (1000 classes of 1.28 millions of images).

Process of training is next:

1. Cut off last output layer with 1000 neurons;
2. Add two fully-connected layers (256, 64 neurons) with RELU activation;
3. Add output layer with 46 possible outputs with SOFTMAX activation;
4. Freeze all weight except just added;
5. Train new weights for 10 epochs with ADAM optimizer;
6. Unfreeze all other weights;
7. Fine-tune all weights for 10 epochs with very small learning rate, like (0.001).

Following approach described above, we have achieved 0.76 top 3 accuracy (top 3 means that observation is classified correctly if true value is predicted in top 3 classifier's outputs).

Then deep image features could be extracted from network using activation of layer before two last layers, which perform classification. In our case – they are 1000 numeric vectors. After the whole dataset of ~290 thousands of images was processed to extract features vectors, comparison was performed using Euclidean distance. Achieved results are on Fig.2.

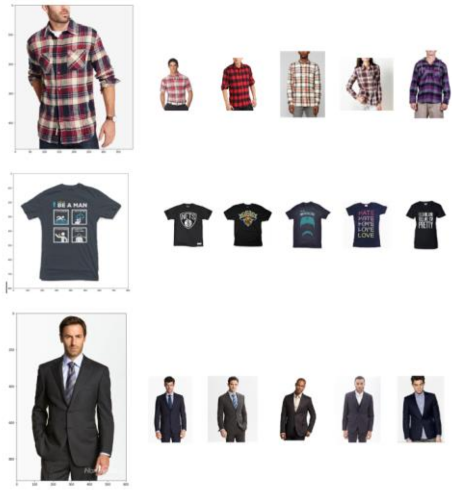

Fig.2. Visual recommendations (first column – input images, next columns – visually similar, sorted by distance, starting from the closest one)

These kind of recommendations are not final. They could be improved by incorporating into feature vector information, related to e.g., color, style, patter.

3 Conclusions

Deep features give an ability to extract information from a visual content that is important for specific task. In our work, we have showed that models, which are used to extract these features, could be trained easily on small data sets using such technique as fine-tuning.

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