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Converging on mutual harmony of knowledge-based expert system and technology consultant

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Abstract. In the Society 5.0, the adoption of advanced technologies in many fields has large positive impacts on the way people think and behave as well as how the companies provide services for any other businesses. In adopting new technology, however, the businesses require significant efforts and deep insights on how to implement such technology that offers large benefits for their businesses. This attempt is typically in line with the one conducted by many consulting firms which provide solution services on how the new innovation and technologies can be implemented and aligned with business goals. With regards to that, this paper focuses on the implementation of a knowledge-based expert system as a technology consultant to recommend suitable technological solutions in supporting the existing teaching and learning activities at educational institutions. A number of tasks have been executed in the research in order to build a reliable expert system, such as properly using design knowledge ontology, formulating if-then rules and reasoning, expert system structure and user interface, and so forth. The resulting knowledge-based expert system demonstrates promising performance and permits to its integration with machine learning techniques for automated knowledge acquisition. This knowledge-based expert system can be a mutual supports in harmony to the human consultants on providing their technology consultancy services.

Keywords: rule-based system, inference engine, artificial intelligence, consultancy business, teaching and learning technologies

1. Introduction

Living in the era of Society 5.0 [1], the ubiquitous leverages of technologies have offered large market opportunities for new businesses whereas the talented people are considered to have prominent contributions to establish such technologies. Thus, it is not a coincidence that many large companies that can sustain in the tough market are technology companies, like financial technology companies [2]. This is due to the fact that most of technology companies can perform better according to the measurements such as their median operating margin which are twice that of median S&P company [3]. It is not surprising that some companies are transforming themselves into a technology companies [4]. It raises the question then, what kind of impact does technology has that make it so ubiquitous to the lives of many people in the 21st century and transforming many companies into technology provider.

One of the impacts of technology that can be seen recently is the fact that many company's successes in the last few decades has been related to their ability to effectively implement an information



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technology that supports for Society 5.0 [5]. It aims at improving company's competitive advantage by effectively implementing Society 5.0. One usage example of information technology is through the implementation of integrated information system like enterprise resources planning (ERP) software in support of automating and improving the efficiency and effectiveness of business processes for the enterprises [6]. Despite the positive benefits of IT/ERP implementations, there exist some challenges due to problem complexity related to technical and non-technical aspects in the company. In order to mitigate such risk, a company may require discussing it with subject matter experts. A consultation with technology consultants is one way to achieve the project success.

While one may see the drawback of consulting in a negative manner in spite of an opportunity to be seized. The drawback indicates an area for improvement. One of the most likely candidates having capability of complementing technology consultants and improving the consultancy results is by leveraging artificial intelligence. It can mimic the cognitive and inference functions that a human has in solving a problem [7-10]. One branch of artificial intelligence that has close connection to these consultancy objectives is so called expert system.

This paper focuses on designing and implementing an expert system that has capabilities in technology solution consultants by creating better knowledge base and accurate inference engine for identifying the technology requirements in educational institutions, as well as evaluating the expert system's reliability and accuracy in substituting technology consultant.

2. Technology consulting and expert system

2.1. Some trends on technology consulting

Technology consulting is one of the terms in consulting that has a narrower focus, so it has better possibility for expert system implementation. A technology consulting is the practice of helping clients transform the way they operate the businesses using technology [11]. Originally, the transformation conducted was geared towards improvement of business processes, costs reduction and more. More recently, technology consulting now encompasses much more than that; starting from digital strategy to projects about technological change [12].

In order to build a system, one must understand what the system is built for. In the context of this paper, it is about substituting a consultant with an expert system [13]. The term of consulting is generally used to refer to management or strategy consulting. In that industry, the consultant is doing the practice of helping companies to increase both their efficiency and profits. This can be achieved by addressing major operational or strategic challenges that a consultant's clients facing. However, such definition is too broad for any expert system.

2.2. Consultancy using artificial intelligence

Artificial intelligence is the science of making and engineering intelligent machines, most importantly intelligent computer programs [14]. It has similarity with the task of using computers in order to understand human intelligence; however it does not mean that artificial intelligence has to be confined to methodology that are observable biologically. Its applications are mostly associated with any intellectual task [7, 15]. One branch of artificial intelligence is so-called expert system, where a computer program has a capability of making an inference towards a decision making similar to a human expert judgement. In the application of expert system, the systems will be designed to solve complex problems not by conventional procedural code but rather by using reasoning over bodies of knowledge that is represented as if-then rules.

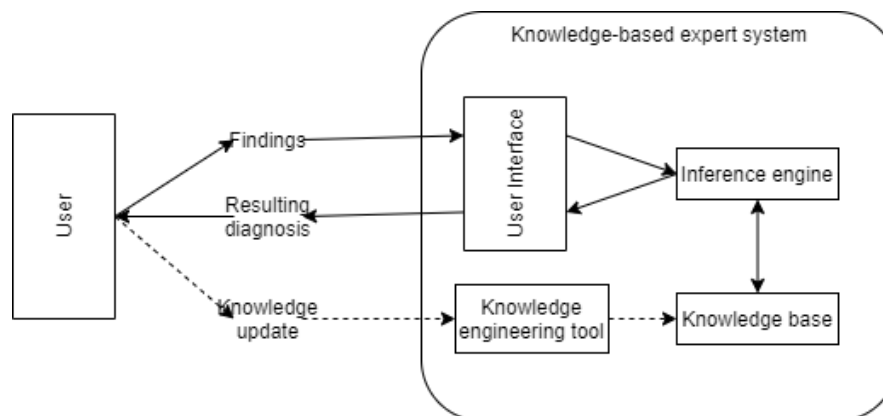


Figure 1. The Components of Knowledge-Based Expert System and Their Connections

2.3. Expert system as recommendation system

One artificial intelligence output by providing sufficient data, criteria and objectives is a recommendation. A knowledge-based expert system enables to perform as a recommendation system. It is one of the systems that make use of knowledge-based system. Several essential components of expert system should be developed in order to provide a reliable and precise recommendation as depicted in Figure 1, comprising of: (1) knowledge base, (2) inference engine and (3) user interface. A knowledge base is a medium for spreading data and information using a centralized database. Its uses are to collect, retrieve, organize, as well as sharing knowledge. On other hand, the inference engine is one of the components of an expert system that tries to search a solution by carrying out reasoning. The way it carries out its reasoning is by matching facts that was given to the database with rules that has been laid out in the rule base. The primary task of an inference engine is the selection of and the application of the most appropriate rule at every step of the expert system session, or so-called rule-based reasoning [13].

The knowledge-based expert system proposed here has a quite unique type of application that can perform as technology consultant and is specifically able to provide technological solutions for educational institutions in order to improve their teaching and learning activities. Since this paper was started, the authors have not found any reference or other authors having this application to technological consultancy. In terms of methodologies used, they do not differ too much from the previous works by other authors. However, as we utilized Python language in the expert system implementation that allows for more integration with other machine learning techniques, the novelty in producing accurate and reliable solutions through better inference engine and reasoning by expert system is expected.

3. A methodology of building an expert system

A standard methodology was utilized in building an expert system, depicted as a flowchart in Figure 2.

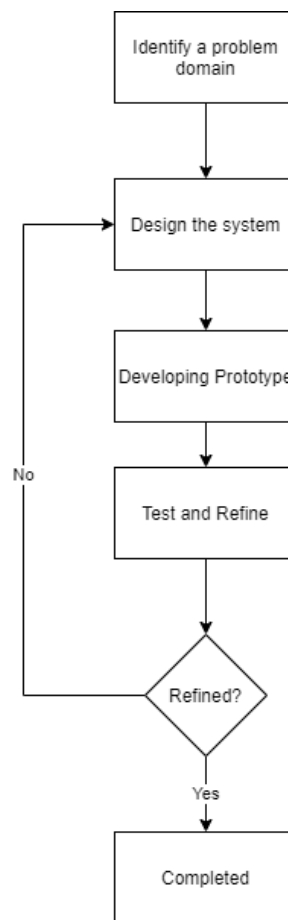


Figure 2. A Standard Methodology in Developing Knowledge-Based Expert System

The step by step tasks must be performed properly and some improvements should be done incrementally by producing a prototype. Some details for each step are described as follows.

(1) Identify a problem domain

An expert system needs to have a narrow focus in order to function properly because a computer program does not differentiate context like human does. The problem domain in this paper focuses on solving the problems of how to provide technology-based teaching and learning facilities in educational institutions.

2) Design the expert system

Several tasks and design tools can be used in this stage, like components diagram, ontology and list of if-then rules.

3) Developing Prototype

An expert system prototype is developed by writing software codes. Many logic programming languages can be utilized, which allows for backward and forwarding chain reasoning, such as lisp, prolog and pyknow.

4) Test and Refine

After developing the prototype successfully, testing and refining the prototype needs to be done. This is conducted in order to make the capability of the expert system on par with an actual human expert. To achieve this, consultation with the domain expert – in the context of this paper a technology consultant who has worked for educational institution – should be conducted. Then after confirming the expert system's capabilities on making decisions like a technology consultant expert, the system is tested based on user requirement and satisfaction.

4. Design and implementation of expert system as technology consultant

4.1. Designing semantic net

One general abstraction of a knowledge-based system is through the usage of ontology. A type of ontology is a semantic net diagram that describes the semantic relations between concepts mapped in a network diagram [16]. In designing expert system as technology consultant for educational institutions [17], we differentiate the concepts into two categories, solution and goal factors, as shown in Figure 3 and Figure 4, respectively.

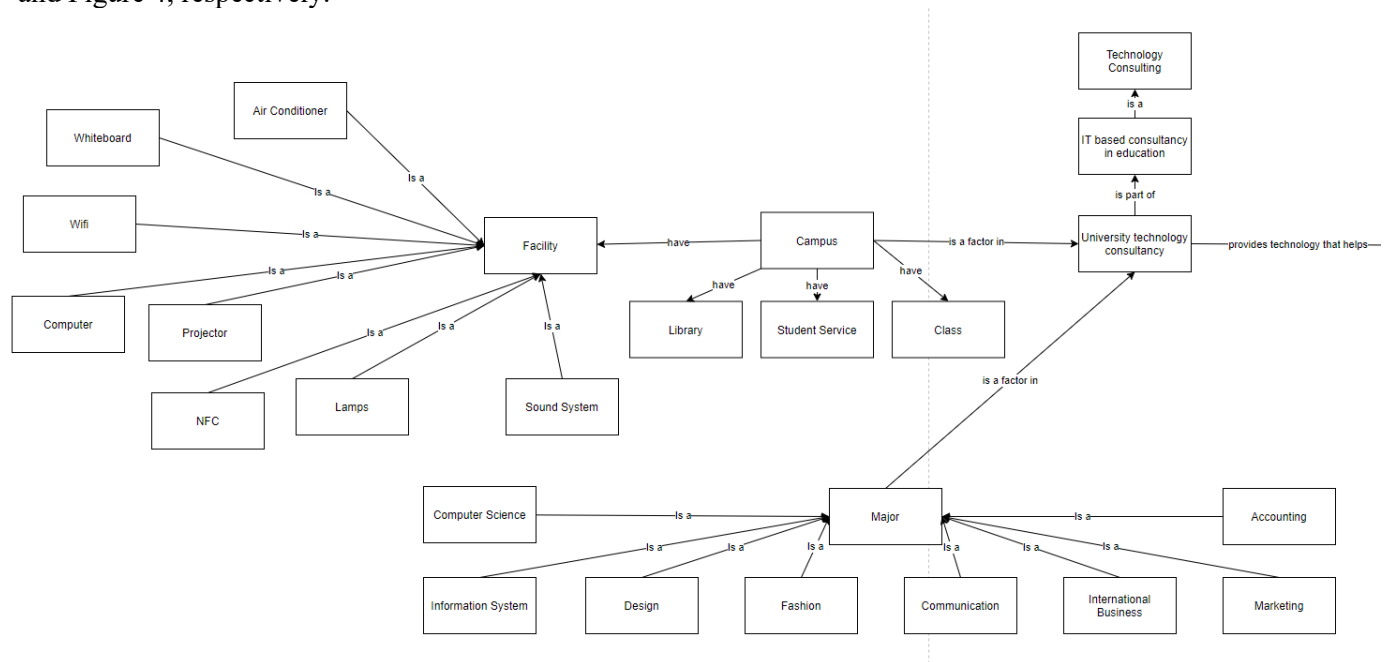


Figure 3. A Solution-Based Semantic Net of Expert System as Technology Consultant

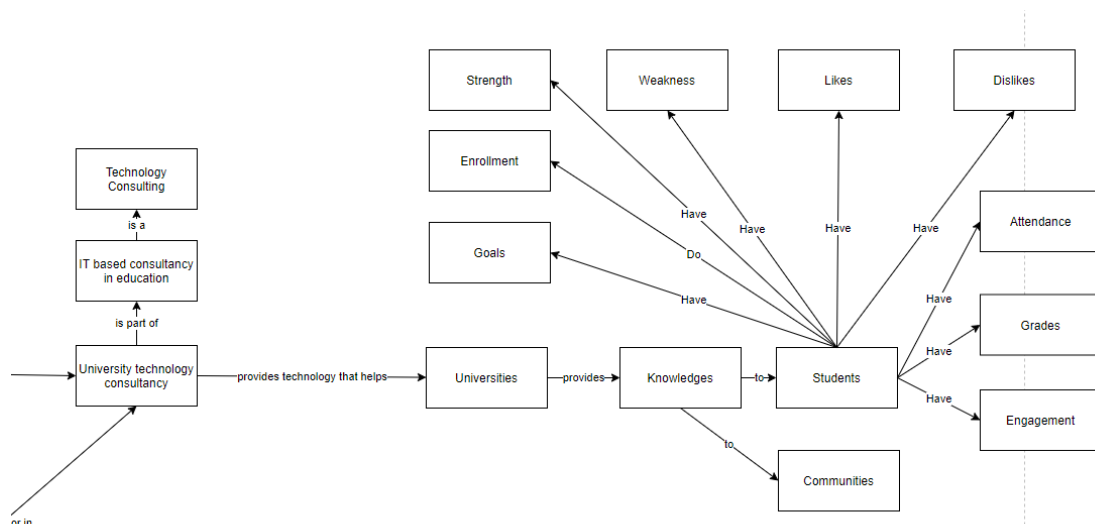


Figure 4. A Goal-Based Semantic Net of Expert System as Technology Consultant

The solution factors semantic net identifies words that the expert system provides a solution when a user is using it. For instance, this semantic net can provide comprehensive knowledge ontology

associated with technology facilities supporting teaching and learning activities in educational institution, such as wireless internet connection, computer and projector (Figure 3). On other hand, the goals factor semantic net characterizes the words given by the user to understand goals that they are trying to achieve when using the expert system. As an example, this semantic net describes some semantic relationship between students or university and students' grade or university goals achievements (Figure 4).

4.2. Knowledge base data description

A knowledge base as a central knowledge source of the expert system utilizes a data management technology that permits to store and retrieve unstructured or structured information provided to/by the expert system. The main structure of knowledge base for an expert system as technology consultant is listed in Table 1. Various data types and values were defined properly to represent the real application of the expert system in educational institutions.

Table 1. A Structure of Knowledge Base for An Expert System as Technology Consultant

No	Attributes	Values
1	Name	String(30)
2	Organization	String(30)
3	Problem	Category(1=lowStudentsPerformance; 2=notEnoughComputer;3=No online material available)
4	Area	Category(1=Student, 2=Organization Performance)
5	Enrollment Goal	Int(10)
6	Actual Enrollment	Int(10)
7	Grades Goal	Int(10)
8	Actual Grades	Int(10)
9	Major	Category(1=Computer Science, 2= Information System, 3=Graphic Design, 4=Fashion, 5=Communication, 6=Accounting, 7=Marketing, 8=International Business)
10	Facility	Category(1=Computer, 2=Air Conditioner, 3=Portal, 4=Projector)
11	No. of Student	Int(10)

```

Rules

Goal Information gathering:
  • IF (action='greet') THEN ask_name
  • IF (Fact(name=W())) THEN ask_organization
  • IF (Fact(organization=W())) THEN ask_problem
  • IF (Fact(problem=W())) THEN ask_area
  • IF (Fact(area='student')) THEN ask_enrollment_goal
  • IF (Fact(enrollmentGoal=W())) THEN ask_actual_enrollment
  • IF (Fact(actualEnrollment=W())) THEN ask_grades_goal
  • IF (Fact(gradesGoal=W())) THEN ask_actual_grades

Solution Information gathering:
  • IF (Fact(gradesGoal=MATCH.gradesGoal) < Fact(actualGrades=MATCH.actualGrades))
    THEN ask_major
  • IF (Fact(major=W())) THEN ask_facility
  • IF (Fact(facility=W())) THEN ask_number_of_student
  • IF (Fact(numberOfStudent=W()), Fact(facility=~L['Portal'])) THEN suggest_portal
  • IF (Fact(numberOfStudent=MATCH.nos), Fact(facility=~L['Computer'])) THEN
    suggest_computer
  • IF (Fact(facility=~L['Air Conditioner'])) THEN suggest_air_conditioner

```

Figure 5. A Set of Main If-Then Rules for An Expert System as Technology Consultant

4.3. Formulating if-then rules

In order to devise a reliable inference engine, a set of main if-then rules were formulated to offer a good solution and recommendation provided by the expert system. The if-then rules written in Pyknow syntax [18] can be seen in Figure 5. There are two groups of if-then rules aiming at gathering: goal and solution information from the expert system users. For the goal information, some information like the user name, organization name, current problem, area, enrolment goal, actual enrolment, grade goal and actual goal could be partly or fully attained from the users through human and expert system dialogs and interactions. While in the solution information, the if-then rules attempt to obtain additional information if some criteria are fulfilled. For instance, if the grade goal is less than the actual goal, then study major information must be attained in order to find more proper solution provided by the expert system. The other information required include the current available facilities, number of students, portal existence, as well as checking whether the computer and air conditioner are available or not.

4.4. Expert system prototyping

For the expert system to function properly, it has to use the appropriate if-then rules in supporting a reliable inference engine. In the context of expert system as technology consultant, a forward chaining is utilized since it tries to figure out a solution by looking at on how the starting point aligns with a set of predefined parameters, similarly to the human technology consultants do.

A prototype of the expert system was done by implementing the if-then rules formulation written in Python, as in Figure 6. In particular, these if-then rules were part of KnowledgeEngine.py and this differs from the code containing the knowledge and rules in the main program of Main.py that runs the instance of the techConsulting class from KnowledgeEngine.py. Figure 6 shows a fragment of main pseudo code of the expert system written in Pyknow. This main knowledge engine is in line with the primary if-then rules defined in Figure 5.


```

Pseudo Code of the expert system

Main.ipynb
Import pyknow
Run techConsulting class

KnowledgeEngine.py
Import engine
Create techConsulting engine(use the rules written in rule-based representation as the rules here)
Def facts
  IF (action='greet')
    THEN ask_name
  IF (Fact(name=W()))
    THEN ask_organization
  IF (Fact(organization=W()))
    THEN ask_problem
  IF (Fact(problem=W()))
    THEN ask_area
  IF (Fact(area='student'))
    THEN ask_enrollment_goal
  IF (Fact(enrollmentGoal=W()))
    THEN ask_actual_enrollment
  IF (Fact(actualEnrollment=W()))
    THEN ask_grades_goal
  IF (Fact(gradesGoal=W()))
    THEN ask_actual_grades
  IF (Fact(gradesGoal=MATCH.gradesGoal) < Fact(actualGrades=MATCH.actualGrades))
    THEN ask_major
  IF (Fact(major=W()))
    THEN ask_facility
  IF (Fact(facility=W()))
    THEN ask_number_of_student
  IF (Fact(numberOfStudent=W()), Fact(facility=~L['Portal']))
    THEN suggest_portal
  IF (Fact(numberOfStudent=MATCH.nos), Fact(facility=~L['Computer']))
    THEN suggest_computer
  IF (Fact(facility=~L['Air Conditioner']))
    THEN suggest_air_conditioner

```

Figure 6. A Fragment of Main Pseudo-Codes for the Expert System

4.5. Testing and analysis

A unit testing analysis was performed in order to analyze whether a developed system can achieve its intended goals. As previously stated, one of the objectives is to implement an expert that has capabilities in providing technology consultancy for educational institutions. Through proper designs, data and rules, the resulting expert system is able to provide fundamental solutions or recommendations to improve the process of teaching and learning activities by proposing new technologies to be used in the class or laboratory rooms. The scenarios were performed to test the expert system, as shown in Figure 7, Figure 8 and Figure 9.

Running the expert system and triggering all suggestion

```

Welcome to untangle system for tech consulting! We will begin the session soon
SECTION ABOUT YOURSELF/ORGANIZATION
What is your name? Titus
What is the name of your organization? Untangle
What kind of problem do you think you are facing right now? Student's grade
It is a problem that relates to students or the performance of your organization? student
What is your organization's goal for student enrolment? 150
How many students are currently enrolling every year? 150
What is your organizations goal for student's grades? 85
What is your student's actual grades? 80
What major do you want to select? Information System
What facility you currently provide? Projector

```

```

How many students is in the class? 20
Okay Titus for Information System major you need 20 computers in a class.
Maybe you need portal to help student access materials from lecturers
Maybe not having air conditioner and having hot room temperature distracts the students

```

Figure 7. User and Expert System Dialogs and Solutions by Triggering All Suggestions

The user and expert system dialogues and solutions for a scenario of triggering all suggestions are illustrated in Figure 7. A number of facts such as names of the user and organization, the problem, number of enrolled students, the goal and actual goals and so forth, are dynamically attained to ensure that the inference engine has sufficient facts to make an inference. The questions asked are changing dynamically based on the user's answers. In this scenario, all possible suggestions are triggered due to lacks of technological facilities in that educational institution. Some recommendations comprise of 20 computers in a class, a portal for accessing teaching and learning materials and air conditioners that must be available to support the educational institution.

Running the expert system and triggering specific solution

```

Welcome to untangle system for tech consulting! We will begin the session soon
SECTION ABOUT YOURSELF/ORGANIZATION
What is your name? Titus
What is the name of your organization? Untangle
What kind of problem do you think you are facing right now? Student's grade
It is a problem that relates to students or the performance of your organization? Student
What is your organization's goal for student enrolment? 150
How many students are currently enrolling every year? 150
What is your organizations goal for student's grades? 85
What is your student's actual grades? 80
What major do you want to select? Information System
What facility you currently provide? Computer
How many students is in the class? 20
Maybe you need portal to help student access materials from lecturers
Maybe not having air conditioner and having hot room temperature distracts the students

```

Figure 8. User and Expert System Dialogs and Solutions by Triggering Specific Suggestions

The scenario for triggering specific solutions based on the user and expert system dialogs is described in Figure 8. Similarly, to the first scenario, a number of questions were asked but with some differences on the answers. In particular, the organization goal is fulfilled by exactly 150 students enrolled. Two recommendations are provided in this case.

Running the expert system and not triggering any solution because all conditions are met

```

Welcome to untangle system for tech consulting! We will begin the session soon
SECTION ABOUT YOURSELF/ORGANIZATION
What is your name? Titus
What is the name of your organization? Untangle
What kind of problem do you think you are facing right now? Student's grade
It is a problem that relates to students or the performance of your organization? student
What is your organization's goal for student enrolment? 150
How many students are currently enrolling every year? 150
What is your organizations goal for student's grades? 80
What is your student's actual grades? 85
You have met your goals. The system can only suggest if you have goals that have not been reached.

```

Figure 9. User and Expert System Dialogs and Solutions Without Triggering Any Suggestion Since All Conditions are Met

Lastly, for the scenario where all conditions are met as illustrated in Figure 9, the number of questions is less since the expert system notices all the required facts are fulfilled based on the standard requirements defined in knowledge base and rules. There is no recommendation triggered in this case due to the fact all of the technology requirements for supporting teaching and learning activities are already implemented in this educational institution. For every if-then statement is executed based on the logical rules, the recommended solution is triggered. According to the expert system run that has been conducted, the expert system module works as it is intended.

5. Conclusions

Despite having many applications of expert systems in medical science, psychology and engineering, this research finds that this leverage of a knowledge-based expert system as technology consultant is still quite new. Technology consultancy services have been emerging fast on par with the developments of Society 5.0. As the high demands of talents and professionals on providing technology consultancy services specifically for educational institutions, this knowledge-based expert system as technology consultant was designed and implemented by utilizing proper knowledge ontology, if-then rules, reasoning and logic programming. Using various scenarios, the unit testing and analysis of the resulting knowledge-based expert system has demonstrated that it has capabilities to provide some prominent technology recommendations to improve teaching and learning activities in educational institutions. Such technology permits to be utilized in mutual harmonious supports to the existing human technology consultants. Further step of this work will be refining the inference engine and knowledge base to cope more complex problems and solutions as well as integrating machine learning techniques for automated acquisitions of the external crucial knowledge into the expert system.

Acknowledgement

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References

- [1] Fukuyama M 2018 Society 5.0: Aiming for a new human-centered society *Japan Spotlight* vol. 1 p 47-50.
- [2] Siek M and Sutanto A 2019 Impact analysis of Fintech on banking industry *International Conference on Information Management and Technology (ICIMTech)* p 356-361.
- [3] McGrath M E 2000 *Product strategy for high technology companies* (McGraw-Hill).
- [4] Walker V, Bowkett G and Duchaine I 2018 All companies are technology companies: Preparing Canadians with the Skills for a digital future *Canadian Public Policy* **44** p S153-S158.
- [5] Fukuda K 2020 Science, technology and innovation ecosystem transformation toward society 5.0 *International Journal of Production Economics* **220** p 107460.
- [6] Martynov V V, Shavaleeva D N and Zaytseva A A 2019 Information Technology as the basis for transformation into a digital society and industry 5.0 in *2019 International Conference "Quality Management, Transport and Information Security, Information Technologies (IT&QM&IS)"* p 539-543.
- [7] Russell S and Norvig P 2002 *Artificial intelligence: a modern approach* (3rd Edition).
- [8] Solomatine D P and Siek M B 2006 Modular learning models in forecasting natural phenomena *Neural networks* **19** p 215-224.
- [9] Siek M and Solomatine D 2010 Nonlinear chaotic model for predicting storm surges *Nonlinear Processes in Geophysics* **17** p 405-420.
- [10] Siek M and Ryan M 2019 Process mining with applications to automotive industry in *International Conference on Multidisciplinary Research*, Bogor, Indonesia.
- [11] Evers H D and Menkhoff T 2004 Expert knowledge and the role of consultants in an emerging knowledge-based economy *Human Systems Management* **23** p 123-135.
- [12] Nicolaou A I 2004 Firm performance effects in relation to the implementation and use of enterprise resource planning systems *Journal of information systems* **18** p 79-105.

- [13] Krishnamoorthy C and Rajeev S 2018 *Artificial intelligence and expert systems for engineers* (CRC Press).
- [14] Davenport T H and Ronanki R 2018 Artificial intelligence for the real world *Harvard business review* **96** p 108-116.
- [15] Siek M and Solomatine D 2011 Real-time data assimilation for chaotic storm surge model using narx neural network *Journal of Coastal Research* p 1189-1194.
- [16] Konar A 2018 *Artificial intelligence and soft computing: behavioral and cognitive modeling of the human brain* (CRC press).
- [17] Verma M 2018 Artificial intelligence and its scope in different areas with special reference to the field of education *Artificial intelligence* **3**.
- [18] Della Porta M G, Malcovati L, Cazzola M and Bellazzi R 2019 A Rule-Based Expert System for Automatic Implementation of Somatic Variant Clinical Interpretation Guidelines in *Artificial Intelligence in Medicine: 17th Conference on Artificial Intelligence in Medicine, AIME 2019, Poznan, Poland, June 26-29, 2019, Proceedings* p 114.