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DEVELOPMENT OF PROBLEMS FOR THE DISCIPLINE "DATA ANALYSIS"

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DEVELOPMENT OF EDUCATIONAL MATERIALS FOR THE DISCIPLINE "DATA ANALYSIS"

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The work is devoted to the methodology of creating educational tasks for disciplines related to data analysis, artificial intelligence, computer vision. The paper proves the possibility of adapting specific tasks for automated testing in the DOTS system, developed an algorithm and templates for creating similar tasks.

The work presents content that will help pupils and students learn key concepts and skills in data processing: detection of missing values and anomalies, classification and clustering, etc.

The work highlights modern methods and approaches to the preparation of educational materials, the importance of adapting materials to the needs of the labor market and rapidly changing technological and analytical trends.

The work can be useful for teachers of IT disciplines who want to improve and automate the educational process. In addition, it may interest specialists in the field of information technology and data analysis who are looking for innovative methods of teaching and learning.

Keywords: educational materials, data analysis, test automation, Pandas, NumPy, OpenCV.

CONTENT

INTRODUCTION

In the modern information society, data processing and analysis are becoming an integral part of various fields of activity, therefore, the development of effective teaching methods and the creation of materials in this area are extremely important.

The chosen topic of the work, "Development of tasks for the discipline "Data Analysis", is relevant due to the need to improve educational programs and teaching methods using modern approaches and technologies.

The purpose of this work is to create effective tasks aimed at practicing basic knowledge and skills in the field of data analysis.

Tasks:

1. Develop and adapt educational tasks for the DOTS system, which are aimed at developing skills in data analysis, artificial intelligence and computer vision;

2. Create templates for automated testing of similar tasks in the DOTS system;

3. To make a useful tool for teachers to automate the educational process;

4. To improve the educational process and training of future IT specialists, contributing to the improvement of the DOTS system.

The project of developing tasks for the discipline "Data Analysis" provides for improving the quality of training of pupils and students - future IT specialists. The subject of the work is the development of problems from the basics of data science, suitable for automated testing in the DOTS system.

The problem sets presented in the work are aimed at generalizing the key concepts and skills of working with Python programming language libraries, such as Pandas, NumPy and OpenCV.

The "Introduction to Data Science" course is taught at universities in various IT specialties. Automation of verification will facilitate and speed up the process of

evaluating students' works, will help introduce more effective teaching methods into the educational process.

An important aspect of the work is taking into account the requirements of the labor market and rapid changes in technologies and analytical trends. It is hoped that the work will be useful not only for teachers of IT disciplines who seek to improve and automate the educational process, but also for specialists in the field of information technology and data analysis who are looking for innovative approaches to teaching and learning.

CHAPTER 1

METHODOLOGY FOR THE DEVELOPMENT OF PROBLEMS FOR THE DOTS SYSTEM

DOTS is a test system for dots.org.ua. The DOTS testing system was developed at the Youth Scientific Society in 2006-2007 for programming competitions. Later, this system was transformed into a powerful specialized LMS for teaching programming, algorithms and data structures. Now the DOTS system works on dozens of subdomains of general educational institutions, universities, individual departments, programming circles, for example, qbit.dots.org.ua, ag45.dots.org.ua, nure.dots.org.ua, hneu.dots.org. ua etc.

1.1. The working principle of the DOTS testing system

The web interface of the DOTS testing system provides pupils and students with access to sets of algorithmic tasks. Such sets of tasks are called contests or tournaments, they are created by users with teacher rights.

The solution to the problem is a text file with the program code, which is written in one of the allowed programming languages. If the user believes that he has solved a problem, he sends it for verification through the interface of the testing system.
The test result is provided through the testing system within minutes of sending. You can send solutions to the same problem several times or alternate parcels of solutions to different problems.

Verification of the solution program is carried out by automatically running it on several secret sets of input data (tests). A particular test is counted as correct if the program completed its work in the specified time, did not exceed the memory limit, and the format and content of the output data is correct for that test. The problem solution is considered correct if and only if it successfully passed all the tests. In most

types of contests supported by the DOTS testing system, the solution can be partially scored.

In figure 1.1. a block diagram of the algorithm of the DOTS testing system is presented.

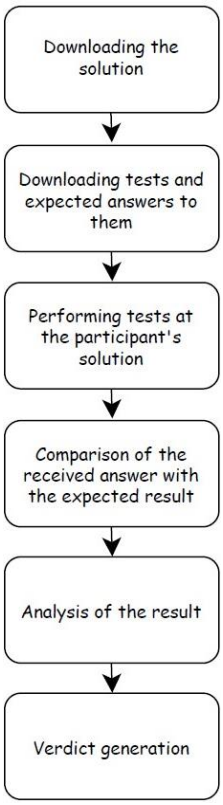

Fig. 1.1. Block diagram of the algorithm of the test system

1.2. Development and execution of the task conditions

The conditions of tasks used in the DOTS system are developed in LaTeX [1]. Listing 1.1 presents a template of a problem condition in the DOTS system.

```
\begin{problem}{Task Name}{input}{output}{Time Limit}{Memory Limit}

% Тут умова задачі

% Далі треба чітко описати формат вхідних даних

\InputFile

% Далі треба чітко описати формат вихідних даних
```

```
\OutputFile

% Далі треба вказати обмеження на вхідні дані

\Constraints

% Приклади

\Examples

\begin{example}

\exmpfile{01.in}{01.out}%

\exmpfile{02.in}{02.out}%

\end{example}

% Пояснення до прикладів (за потреби)

\Explanations

\end {problem}
```

Listing 1.1. Task template (LaTeX)

After preparing the condition of the problem, the LaTeX file is converted to an image using a special bash script, which is shown in Listing 1.2.

```
#!/bin/bash

cd statements

cat begin.document_ua problem_ua.tex end.document > prob_ua.tex texi2pdf prob_ua.tex

pdftoppm -tiff prob_ua.pdf > prob_ua.tif

convert  -transparent white -trim prob_ua.tif problem_ua.png

rm -f *.tif *.pdf *.log *.dvi *.aux prob_*

cd ..
```

Listing 1.2. Bash script makepng.sh

This bash script is a tool for automating the conversion of LaTeX files to images. After moving to the desired directory, the script combines texts from the files "begin.document_ua", "problem_ua.tex", and "end.document" into a new file "prob_ua.tex". This file is then compiled into a PDF using the texi2pdf command. The resulting PDF is converted to TIFF format using pdftoppm.

After converting to TIFF, the script uses the "convert" program to convert the image to PNG format. This process also includes changing the white color to transparent and cropping the image outside.

The script deletes temporary files to get rid of unnecessary junk. After the conversion process is complete, it returns to the previous working directory.

In fig. 1.2 presents an image that can be obtained from an empty template using the makepng.sh script.

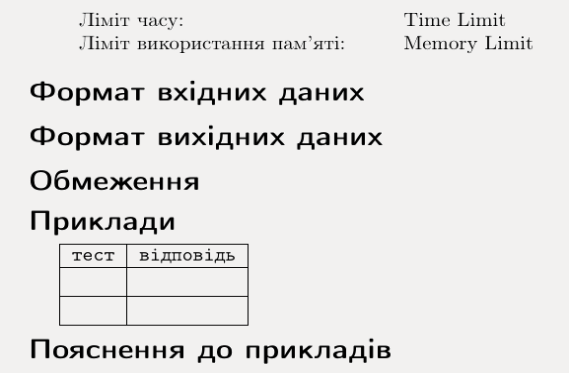

Fig. 1.2. An example of a problem template

1.3. Development of tests for tasks in the DOTS system

Development of tests for tasks in the DOTS system is an important component of the software testing process. The input and output data for such tests are crucial, as they determine the correctness of the algorithms and the correctness of their implementation.

Input data for tasks is a set of parameters that are passed to the algorithm for processing. They contain various values and variants of input scenarios, which allows to evaluate the behavior of the algorithm in different conditions. It is important that the input data are carefully selected, because they determine possible variations in the operation of the algorithm and reflect its adaptability to different input conditions. Here are some important aspects to consider when designing tests for:

- code coverage. The test input should cover all possible branches of the algorithm code, including all variants of conditions and execution paths;
- extreme and limiting values. It is worth including extreme and limit values in the tests to evaluate the operation of the algorithm in critical conditions;
- data realism. The input data must correspond to real the terms of use of the algorithm;
- comparison with expected results. It is important to check the actual output of the algorithm against the expected results to detect inconsistencies.

Test development is an iterative process in which it is important to control the quality and coverage of all important aspects of the task. When developing tests for the problems presented in this work, the following approaches were used:

- manual development. Usually used to generate small test data to be presented in a problem condition, and sometimes to generate extreme and boundary value tests;
- automated development. Requires writing your own special generator programs that will cover a certain aspect or range of values;
- real data. For tasks on the basics of data analysis, data that can be obtained from open sources is very well suited. These can be, for example, datasets from kaggle or database table dumps.

1.4. Development of checkers and validators

The development of checkers and validators is an important step in ensuring the correctness and reliability of the DOTS test system.

A checker is a program that provides the ability to automatically compare the actual output of an algorithm with the expected results. The checker detects differences

or inconsistencies in the operation of the program, which allows you to quickly determine the correctness of the implementation.

A validator is a program that checks tests for compliance with the formats of input and output data, and also monitors compliance with the restrictions on input data specified in the condition of the problem.

Checkers and validators for the DOTS system are developed using the free library testlib [2].

You can find out more about the practical application of the research results in the implementation guide (Appendix A).

Information on test access data in the DOTS system for familiarization with tasks is provided in Appendix B.

CHAPTER 2
BLOCK OF PROBLEMS "PANDAS"

2.1. Python Pandas library

Pandas [3] is a powerful Python [4] programming language library for data processing and analysis. It provides simple tools for working with tabular data. Pandas allows you to efficiently load, store, process and analyze tabular data using a variety of functions for filtering, grouping, aggregation and visualization. The Pandas library can be used to build machine learning models or process data before further analysis.

2.2. Tasks for using the Pandas library

This section presents five problems, the solution of which involves the active use of the Python Pandas library. Conditions, tests, checking programs, author's solutions have been developed for all tasks.

2.2.1. Task A. "Pandas: sum, max, min"

Function pd.read_csv() [8, p. 11] in the Pandas library is used to read data from CSV files and load them into a DataFrame - the main data structure in Pandas. It allows you to import data from CSV files into Python for further processing and analysis.

The basic parameters of pd.read_csv(), shown in Listing 2.1, include the path to the file containing the data, as well as options to customize the reading process, such as column delimiter, encoding, indexing, and so on.

```
import pandas as pd

df = pd.read_csv('input.csv', sep = ';')
```

Listing 2.1. Reading data from an SCV file and saving it to a DataFrame

Brief condition of the problem: "There is a rectangular table of integers saved in a CSV file. The fields of the table are separated by the character ";", the first row of the table contains the column headings. You need to calculate the sum of all the numbers in the table, and also find the maximum and minimum elements in the table."

The development of tests for this task can be easily automated in any programming language. Testing programs are implemented in the C++ programming language, using the free testlib library.

Detailed information on this and other tasks is located in the repository [7] on GitHub.

2.2.2. Task B. "Average and Geometric Mean"

Using the Pandas library, you can easily and quickly count the number of unique elements in a table, delete columns and rows, create new rows and columns in tables.

Brief condition of the problem: "There is a data table. The table is stored in CSV (Character-Separated Values) format, fields are separated by the character ";". Each cell in this table can be: an integer, a fractional number, empty, filled with whitespace characters (spaces or tabs), or a character string.

You must first remove all rows where not all values are integers. And then delete all columns in which the arithmetic mean of all values is equal to the geometric mean."

The development of tests for this task can be easily automated in any programming language. Testing programs are implemented in the C++ programming language, using the free testlib library.

2.2.3. Task S. "Timestamp"

The Pandas library provides extensive options for working with dates and times in a dataset. Here are some of the main features for handling dates and times in Pandas:

- reading and converting date and time (pd.to_datetime);
- obtaining date and time components;
- sorting by date (df.sort_values);
- grouping and aggregation by periods (df.groupby) [8, p. 13];
- filling in missing dates in the range.

Brief condition of the task: "A dump of one of the database tables was saved in CSV format. This file contains the following data: a time stamp in the timestamp format (POSIX time, that is, the number of seconds that have passed since 00:00:00 UTC on January 1, 1970); user id; task id; score for solving the problem in percentage. You have to find the number of correct decisions within a certain period of time."

The tests for this task were obtained from real data, namely from the database dumps of the DOTS test system. Testing programs are implemented in the C++ programming language, using the free testlib library.

2.2.4. Problem D. "Statistics"

The Pandas library offers a variety of methods for computing statistical metrics. These techniques help extract a wide range of statistical information for numerical data in Pandas DataFrame, allowing basic analysis and understanding of data characteristics.

Brief condition of the task: "A dump of one of the database tables was saved in CSV format. This file contains the following data: a time stamp in timestamp format; user id; task id; id of the programming language, score for solving the problem in percentage. It is necessary to obtain statistics on the use of programming languages from this data."

In the table 2.1 presents statistics on the use of programming languages at the city tournament of young computer scientists.

Table 2.1

Statistics on the use of programming languages

Programming language	Number of authors	Number of solutions	Number of "OK" solutions	Number of "CE" solutions
C++	13	462	67	15
Python	12	144	15	11
C#	4	20	0	3
Pascal	3	9	4	3
JavaScript	3	45	2	2
Java	1	2	0	2
	14	696	88	39

The tests for this task were obtained from real data, namely from the database dumps of the DOTS test system. Checkers lose we are implemented in the C++ programming language, using the free testlib library.

2.2.5. Task E. "Certification"

The Pandas library has a large number of functions for processing and working with data. The most important of them are the grouping or merging of data, as well as the ability to apply a certain function to each element of the table.

Brief condition of the task: "IT SKILLS STANDARD certification determines the level of algorithmic preparation of a pupil or student and consists of three algorithmic contests, each contest contains three tasks. Each certification task is evaluated for a maximum of 100 points, but the verification system provides for the evaluation of incomplete solutions (percentage of the maximum score).

Let the certification participant score p% points, then he can receive the certificate: "Very Good" (if $60 \le p < 74$); "Excellent" (if $74 \le p < 90$); "Outstanding" (if $90 \le p \le 100$).

A dump of one of the certification database tables was saved in CSV format. This file contains the following data: user id; task id; id of the contest, score for solving

the problem in percentage. It is necessary to sum up the results of the certification based on these data."

The tests for this task were obtained from real data, namely from the database dumps of the DOTS test system. Testing programs are implemented in the C++ programming language, using the free testlib library.

CHAPTER 3

BLOCK OF PROBLEMS "NUMPY"

3.1. Python NumPy library

NumPy [5] (Numerical Python) is a powerful library for the Python programming language, designed for efficient processing and analysis of numerical data. NumPy provides high-performance data structures such as arrays and matrices and a rich set of mathematical functions.

3.2. Tasks for using the NumPy library

This section presents five problems, the solution of which involves the active use of the Python NumPy library. Conditions, tests, checking programs, author's solutions have been developed for all tasks.

Problems "B" and "C" have a specific format of input data - NPZ. This is an internal NumPy library format for storing data as arrays using gzip compression. NPZ files can include one or more arrays. This format is efficient for storing and sharing large amounts of data. The np.load() function is used to read NPZ files.

3.2.1. Task A. "NumPy: ones, zeroes, full"

The Numpy library has several simple tools for filling and modifying matrices and arrays [8, p. 6]:

- zeroes() and ones(). Filling arrays with zeros or ones, respectively;
- full(). Filling arrays with a certain value;
- eye(). Creating a unit matrix.

These NumPy methods allow you to create, populate, and generate matrices and arrays with different values and structures, which is useful for further calculations and data analysis.

Brief condition of the problem: "Let N be the dimension of the square matrix. Write a program using the Numpy library that will generate a matrix of N rows and N columns. Fill this matrix with zeros. On the main and side diagonals, as well as on the perimeter, replace the zeros with ones.

The development of tests for this task can be easily automated in any programming language. Testing programs are implemented in the C++ programming language, using the free testlib library.

3.2.2. Task B. "NumPy: sum, max, min"

The NumPy library has a wide set of functions for working with arrays and matrices, which allows you to perform various operations, from mathematical calculations to data manipulation:

- mathematical operations;
- comparison operations and logical operations;
- statistical functions;
- indexing and slices;
- changing the shape of arrays.

Brief problem statement: "The NPZ file stores several one-dimensional numeric NumPy arrays. In each array, you need to find: the sum of all elements;

minimal element; maximum element; indices of all minimal elements; indices of all maximal elements".

Development of tests for this task and recording of input data in NPZ format was automated using the Numpy library. Testing programs are implemented in the C++ programming language, using the free testlib library.

3.2.3. Problem C. "NumPy: where"

In NumPy, you can select elements that satisfy certain conditions using Boolean indices. Here are some examples:

- applying the condition directly to the array:
- arr = np.array([1, 2, 3, 4, 5])
- # Selection of elements greater than 3
- result = arr[arr > 3]
- combining conditions:
- # Select elements that are greater than 2 and less than or equal to 5
- result = arr[(arr > 2) & (arr <= 5)]
- using conditions with two arrays:
- arr2 = np.array([10, 20, 30, 40, 50])
- # Select elements from arr2 for which corresponding elements arr > 3
- result = arr2[arr > 3]
- use of functions:
- # Selection of elements that satisfy a certain condition, for example, np.where
- result = np.where(arr > 3, arr, 0)
- # Selects elements > 3, replaces others with 0

Brief problem statement: "The NPZ file stores several one-dimensional numeric NumPy arrays. In each array, you need to find elements whose value is in the range from 1 to 9 inclusive."

Development of tests for this task and recording of input data in NPZ format was automated using the Numpy library. Testing programs are implemented in the C++ programming language, using the free testlib library.

3.2.4. Task D. "Numpy: poly"

The Numpy library also provides convenient tools for working with polynomials. A large number of different functions have been developed in this library.

Among them are such as: operations of addition, subtraction and multiplication of polynomials, as well as finding the value of a polynomial, its roots, derivative and others.

Brief condition of the problem: "Let P be a polynomial of the nth degree. You know that this polynomial has exactly n real roots. Write a program using the NumPy library that will find the coefficients of the polynomial P; will calculate the value of the polynomial at the given point; will calculate the value of the derivative of the given polynomial at the given points."

The development of tests for this task can be easily automated in any programming language. Testing programs are implemented in the C++ programming language, using the free testlib library.

3.2.5. Task E. "Numpy: linalg"

NumPy is equipped with a large set of functions for performing linear algebra operations. Examples can be functions for solving a system of linear equations, calculating the determinant of a matrix, transposing a matrix, and others.

Brief condition of the problem: " Let A be a rectangular matrix with N rows and M columns. It is known that |M – N| = 2. We need to write a program that deletes two rows or two columns from the matrix A so that the square matrix B with the maximum determinant is obtained.

The development of tests for this task can be easily automated in any programming language. Testing programs are implemented in the C++ programming language, using the free testlib library.

CHAPTER 4

PROBLEM "COUNTING OBJECTS"

4.1. OpenCV Python library

OpenCV [6] (Open Source Computer Vision Library) is a computer vision and image processing library that provides a variety of tools for performing operations on images and videos. It allows you to detect objects, faces, track movement, apply filters, perform color processing, and solve machine learning problems.

4.2. Statement of the problem "Counting Objects"

A PNG image contains a number of rectangles. They can differ in terms of parameters, such as rotation relative to the coordinate axes, color (color or black and white borders and filling) and the shape of the corners (rounded or sharp). It is also worth noting that the rectangles in the image do not intersect and do not overlap each other.

The answer in this problem is one number, it is the number of rectangles in the image.

To solve this problem, the OpenCV Python library is used, which provides tools for image processing and performing computer vision operations. The program is expected to be able to accurately determine the number of rectangles in an image, taking into account their various properties.

4.3. Test generation

A program written in the Pascal programming language using the GraphABC library was developed to generate the tests. It generates test images with rectangles, each of which has different characteristics:

- image size (W, H): The width and height of the image are set by the parameters W (width) and H (height) in the application code. The width of the generated tests is in the range from 100 to 800 pixels. The height of the generated tests is in the range from 100 to 800 pixels;
- the minimum and maximum radius of the circle described near the rectangle (Rmin, Rmax): they are determined by the parameters Rmin (minimum radius) and Rmax (maximum radius) in the program code. The minimum radius of the generated tests is in the range from 10 to 25 pixels. The maximum radius of the generated tests is in the range from 100 to 300 pixels;
- the maximum number of rectangles (Count): The maximum number of rectangles in the image is set by the Count parameter in the program code. The number of generated test rectangles ranges from 100 to 2000. But it is worth noting that the Count parameter is not always the answer to the test. The answer may be smaller when all the rectangles cannot be placed on the image;
- rectangle type. Rectangles can be squares or rectangles;
- colors Ability to generate color or black-and-white border and rectangle filling;
- turn Rectangles can be rotated to a random angle or remain parallel to the coordinate axes;
- the shape of the corners. Rectangles can have rounded or pointed corners;
- coincidence. It is possible to randomly generate all parameters for rectangles.

Four examples of images generated by the program are presented (Appendix B).

70 tests and answers to them were generated to check the solutions. They consist of 7 difficulty blocks:

1. 01-05: Unfilled squares with a black and white border.

2. 06-10: Unfilled rectangles with a black and white border.
3. 11-15: Squares with colored or black-and-white borders, with color or black-and-white filling, with a border of a different or the same color filling.
4. 16-20: Rectangles with a color or black-and-white border, with color or black-and-white filling, with a border of a different or the same color with filling.
5. 21-40: Squares and rectangles with a random angle of inclination.
6. 41-50: Squares and rectangles with rounded corners.
7. 51-70: Tests with random characteristics.

Such a set of tests helps to easily determine whether the program correctly determines the number of rectangles in the image according to the above conditions.

CONCLUSIONS

1. In this work, educational tasks were developed and adapted for use in the DOTS system, aimed at developing skills in the field of data analysis, artificial intelligence, and computer vision. The possibility of adapting the tasks of the "Data Analysis" discipline to the format of automated testing in the DOTS system is shown.

2. Templates have been developed for creating similar tasks, as well as ensuring their automated testing in the DOTS system. The work contributes to improving the quality of training of pupils and students in working with three libraries: NumPy, Pandas, OpenCV. The use of automated testing methods makes training more efficient and faster, which increases the level of training of students.

3. The work can serve as a useful resource for teachers of IT disciplines aimed at improving and automating the educational process. In addition, it can attract the attention of specialists in the field of information technology and data analysis who seek to apply modern methods of teaching and learning.

4. The developed tasks contribute to increasing the effectiveness of education and training of future IT specialists. They also open up opportunities to improve the DOTS system for wider introduction into the modern educational process.

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APPENDIX A

Certificate on the implementation of the results of research work

УКРАЇНА
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30.01.2024 № 68
на №

ДОВІДКА

ння результатів науково-дослідної роботи
Ласкавцевої Софії Дмитрівни, учениці 11 класу КЗ
«Харківський академічний ліцей №45» Харківської міської
ради на тему «Розробка задач до дисципліни «Аналіз даних»»

Розвиток інформаційно-комунікаційних технологій, технологій штучного інтелекту та засобів аналізу даних впливають на всі галузі сучасної економіки, в тому числі й на систему освіти. Потребує змін і зміст підготовки майбутнього вчителя, оскільки саме йому прийдеться готувати покоління учнів до високотехнологічного майбутнього. В ракурсі розв'язання цих проблем знаходиться дослідження Ласкавцевої Софії, яке присвячене розробці набору навчальних задач, пов'язаних із аналізом даних, штучним інтелектом, і комп'ютерним зором.

Розроблені авторські задачі інтегровані у систему автоматизованого тестування в системі DOTS, яка з 2011 року використовується у Харківському національному педагогічному університеті імені Г.С.Сковороди в процесі навчання дисциплін «Основи програмування», «Теоретичні основи інформатики», «Практикум з розв'язування задач з програмування». Для навчального процесу є зручним, що кожна задача, запропонована автором дослідження, супроводжується набором тестів, які уможливлюють автоматизовану перевірку правильності й коректності отриманих розв'язків. Використання матеріалів наукової роботи Ласкавцевої Софії у навчальному процесі університету сприяло розширенню джерельної бази, методичних підходів до викладання дисципліни «Практикум з розв'язування задач з програмування» та «Основи штучного інтелекту» для здобувачів спеціальності 014.Середня освіта (інформатика).

Результати наукової роботи Ласкавцевої Софії Дмитрівни доповідались на засіданні кафедри інформатики (протокол № 12 від 30 січня 2024 р.) й оцінені як такі, що заслуговують на впровадження в практику підготовки майбутнього вчителя інформатики.

Зав. кафедри інформатики
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Підпис Олефіренко
засвідчується зав. канцелярією

APPENDIX B

Accounts in the DOTS system

To familiarize yourself with the tasks and test the solutions to these tasks, test access to the corresponding workshops on programming in the DOTS system is open - https://qbit.dots.org.ua.

- An account for the Numpy workshop

  login: test_numpy

  password: numpy

- Account for Pandas workshop

  login: test_pandas

  password: pandas

- OpenCV workshop account

  login: test_opencv

  password: test_opencv

APPENDIX C

Examples of generated tests for the task "Counting Objects"