Interactive teaching methods with visualization for technical and economic students

Olena M. Mikhailutsa[1], Tatiana O. Melikhova[1], Andriy V. Pozhuyev[1] and Hennadiy M. Kravtsov[2]

[1]Zaporizhzhia National University, 66 Zhukovskoho Str., Zaporizhzhiam 69600, Ukraine
[2]Kherson State University, 27 Universytetska Str., Kherson, 73003, Ukraine

Abstract

Interactive teaching methods are becoming increasingly popular in education, as they offer a number of benefits for students, including increased engagement, motivation, and learning outcomes. This paper analyzes the benefits of using interactive teaching methods for students of technical and economic specialties using visualization as an example. The paper begins by reviewing existing innovative educational methods and focusing on the use of information technology in the formation of competencies of future specialists. Next, the paper presents a comparative analysis of platforms for developing graphic applications as the main means of visualization on the Internet. The paper then describes the implementation of a visualization of the ant colony optimization algorithm, which is a powerful tool for solving logistic problems that are of importance for both economic and technical areas. The visualization includes building a graph, simulating the dynamic network movement of a large number of ants, saving and loading the graph, and providing the user with the ability to remove visible layers. To test the effectiveness of this approach, a multistage experiment was conducted. The results of the experiment allowed the authors to draw a number of positive findings, including: (a) students in the experimental group showed significantly higher levels of engagement and motivation than students in the control group; (b) students in the experimental group performed significantly better on learning outcomes assessments than students in the control group; (c) students in the experimental group were more satisfied with the quality of instruction than students in the control group. In addition, the authors conducted a comparative survey of students from the experimental and control groups to find out the students' needs in the process of dual learning. The results of the survey provided the authors with an opportunity to increase students' satisfaction with the quality of teaching disciplines.

Keywords

interactive teaching methods, visualization, ant colony optimization algorithm, dual learning, student satisfaction

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elenamikhaylutsa7@gmail.com (O. M. Mikhailutsa); tanyu_zp_zgia@ukr.net (T. O. Melikhova); scorpio6828@gmail.com (A. V. Pozhuyev); kgm@ksu.ks.ua (H. M. Kravtsov)
https://scholar.google.com.ua/citations?user=QeeENIMAAAAJ (O. M. Mikhailutsa); http://sites.znu.edu.ua/cms/index.php?action=news/view_details&news_id=46469&lang=ukr&news_code=melikhova-tetyana-olegivna (T. O. Melikhova); http://sites.znu.edu.ua/cms/index.php?action=news/view_details&news_id=46523&lang=ukr&news_code=pozhu--v-andrij-volodimirovich (A. V. Pozhuyev); http://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Kravtsov.aspx (H. M. Kravtsov)
0000-0003-2935-7997 (O. M. Mikhailutsa); 0000-0002-9934-8722 (T. O. Melikhova); 0000-0002-4083-5139 (A. V. Pozhuyev); 0000-0003-3680-2286 (H. M. Kravtsov)

1. Introduction

Freight and road haulage by region is an important part of the Ukrainian economy, with turnover increasing every year. However, enterprises are facing new challenges, such as the need to find optimal routes for the delivery of goods in the context of rising fuel prices and a shortage of qualified personnel in the logistics sector.

One way to address these challenges is to improve the quality of logistics education. Universities should focus on teaching practical problems and using computer programs that are used in the industry. Additionally, universities should adopt a student-centered approach to learning, which will help students to develop the critical thinking and problem-solving skills that are essential for success in the modern economy.

For example, Metinvest holds a case championship with students to get a new perspective on their existing problems. Students have the opportunity to work on real-world problems and develop solutions that could be implemented by the company. This type of experiential learning is essential for preparing students for the workforce.

Another way to improve the quality of logistics education is to develop innovative teaching methods that stimulate creativity and self-development among students. One possible approach is to use project-based learning. In project-based learning, students work on real-world projects that are relevant to their field of study. This approach helps students to develop the skills and knowledge they need to be successful in the workplace, as well as the creativity and problem-solving skills that are essential for success in the 21st century.

By improving the quality of logistics education, universities can help to prepare students to meet the challenges of the modern economy and contribute to the technological modernization of Ukraine.

2. Literature review

The list of key tasks and a description of the global problem considered in this paper are based on a review and analysis of publications. Speaking of visualization in general, its application for strategic planning by studying the use of interactive visual representations in real time in business strategy process, and the role of visualization in assessing and transferring risks are analyzed by Eppler and Aeschimann [1], Eppler and Platts [2], Bondarenko et al. [3]. Osinska and Osinski [4] studied the use of information visualization in the social and human sciences, while covering a wide range of topics, including analysis of social networks, complex systems, as well as issues of visualization aesthetics.

The research experience gives a real opportunity to generalize and systematize ideas about teaching methods and technologies. In article of Fırat and Laramee [5], visualizations of pedagogical research work are analyzed and classified, determining the directions of open research subjects in an interactive visual representation for education, which demonstrate the impact of visualization methods on advanced training. The demonstration of visualization possibilities in computer science and mathematics [6] emphasizes the effectiveness of its use to improve various types of activities in the educational process.

Emphasizing the fact that modern educational space consists of two types of pedagogical

processes – innovative and traditional, Panina [7] identified the differences between traditional and innovative schools at the level of educational technology. Attention is paid to the description and systematization of the most popular and frequently used innovative educational methods of teaching in higher education. According to Tarasenko et al. [8], Malchenko et al. [9], Bilousova et al. [10] the effective use of interactive teaching methods will allow the preparation of qualified, competitive, educated and intellectually developed specialists. In the presented classification of interactive methods, the case-study method is separately highlighted; it allows students to take the initiative in mastering theoretical positions and mastering practical skills [11, 12].

Focusing on the process of developing educational visualization, Hauswirth [13] promotes the development of pedagogical methods and tools that allow students to learn while creating visualizations on their own. It is well known that socioeconomic changes and information development of the entire world community require the use of information technology in the formation of the competencies of future specialists. By putting more emphasis on the development of algorithmic thinking, the didactic potential for the use of algorithms visualization systems in the process of teaching programming was considered by Moglan [14]. The methods of using the created instrumental environment, that is the algorithms of visualizer within the educational process are proposed. However, it should be noted that the implemented visualizers allow you to interactively demonstrate the operation of the algorithms only for processing static structures. The proposed approach can't be applied for the presentation of more complex data structures. The created visualization system is a catalog of implemented visualizations for a fixed algorithm suite without the possibility of adding a new algorithm to a catalog by a third party user.

Analyzing the techniques of visualization of algorithms in order to create an electronic encyclopedia of graphs algorithms, Gordeev [15] considered examples of systems for visualizing them. The advantages of an event-oriented approach and a data-oriented approach and their change are analyzed. The given examples of existing visual techniques for describing the graph algorithm behaviour are considered from the standpoint of having the ability to specify parameter graphs by the user, the ability to specify parameter algorithms, and the ability to adjust the visual part of the image. A comparative description of existing software products for graph analysis is presented in detail in [16]. The authors presented a software package for the analysis and visualization of large graphs. The cross-platform nature of the used implementation tools and the ability of the developed software complex to function in various operating systems allows it to be used in the tasks of sociological and marketing analysis.

The popularity of effective "swarm intelligence" methods explains the constant appearance of a modification of the ant colony method to solve various applied problems [17]. Panteleyev and Alyoshina [18] proposed an algorithm for solving the shortest path search problem on an oriented graph using the ant colony method. The corresponding software is presented, the performance of which is demonstrated by a specific example. However, the authors have not sufficiently studied the question of the convergence of the method, in particular, the speed of its convergence.

The analysis of these works allows us to conclude that for most visualization systems the introduction of a new algorithm requires the development of the whole visualization system from scratch. In light of the fact that the use of automated systems in the transport logistics branch is one of the ways to save resources, even with a large number of ant algorithms already

implemented, it is necessary to further implement and improve these algorithms to find the best results.

Many works are devoted to the transport logistics issues [19, 20]. Thus, Bowersox et al. [21] describes the role and content of logistics in modern business, as well as examines in detail two fundamental tasks facing managers: developing an appropriate logistics structure and overall management of logistics activities. Stock and Lambert [22] focuses on the marketing orientation, and subject matter is reviewed in terms of customer satisfaction. Emphasizing the marketing aspects of logistics, the authors combine all functional business areas, and also include logistics in supply chain management. The compendium [23] presents the latest developments in logistics theory in various fields, as well as case studies. It contains a collection of theoretical topics, practical cases, case studies and project reports. The emphasis is made on knowledge transfer from research to business practices in logistics.

The relevance of the work presented is attributable to the fact that the proposed software product has multidisciplinary scientific and applied aspects: from its research-oriented nature to practical implementation both in the educational process and in the practical activities of industrial and commercial enterprises.

3. Materials and methods

Nowadays higher education institutions are unique in that economists are taught engineering specialties, and future engineers can choose any economic discipline. Some students seek to obtain knowledge of both economic and technical areas at the same time, and while studying in two specialties in parallel, they also use the right to choose their individual learning path. In an engineering institute of Zaporizhzhia National University, teachers and students of different technical and economic specialties work together on the same scientific or educational issue, which allows them to expand their horizons, exchange teaching methods and introduce modern ways in teaching their disciplines. This enriches the knowledge of students of both specialties and improves the quality of education, which subsequently provides them with the opportunity to receive a prestigious profession.

The issue of teaching methods is essentially a question of how to make close contact between the student and the teacher. It is effective to use visualization with various teaching methods as a means of transition from a passive perception of educational material to an active and conscious acquiring of knowledge. In this way, it is easier to comprehend the essence of the technical problem under consideration and the importance of the technical activity performed, as well as to evaluate the optimality and reasonability of the technical solution.

The daily use of algorithms allows humanity to make life easier due to the speed and optimization of tasks. In the 21st century, during the scientific and technological revolution, the use of various algorithms increases almost exponentially, optimizing most production processes. In most cases, it is enough to slightly modify the existing algorithm and apply it in another area in order to significantly increase the benefits of its application. If to highlight the visualization of the ant algorithm [24], it would like to emphasize its alternative way in explaining the decision-making theory to engineering students; it also allows economists involved in transport logistics issues to better understand the material.

3.1. Survey of visualization technologies

The global network is increasingly becoming the main platform for data reproducing (visualization). This applies in particular to interactive data visualization, which allows users to manipulate their data and graphics in real time. Although this move into the Internet opens up many opportunities for global visualization, it is also accompanied by its own set of problems. For example, how to reproduce large amounts of data in a web browser? To understand the problems of visualization, several types of web animation development were analyzed. The most widely used technologies in this direction are SVG, HTML, Canvas and WebGL [25]. The term SVG means "Scalable Vector Graphics". It is an XML-based format for drawing vector images. SVG offers certain benefits as a data visualization tool, in particular ease of comprehension, since it consists of standard primitives such as rectangles, circles and lines. Due to the simplicity of its use and integration with HTML standards, this format is the most common option for graphics on the Internet. However, despite this, SVG has one major drawback – scaling the number of nodes.

The main advantage of Canvas technology is that since it creates bitmaps, it does not have a trace of memory that SVG has with its nodes. Thanks to this, we can easily draw thousands of data points using Canvas. On the other hand, Canvas is like a black box, because after it has been displayed on the screen, all we have is an image. Separately, it is worth mentioning the fact that the usage of interactivity requires much more complex solutions, however, it can process data animation much more efficiently than SVG. Canvas is a good option when you create a visualization that provides more data points than the SVG could handle.

The advantage of WebGL is its productivity, in which 3D graphics, millions of data and animations can be displayed smoothly [26]. The downside is complexity because WebGL is the hardest of the work options, mainly due to the low work level [27]. Most of the visualizations you crave to do on the Internet can be done without the power of WebGL. However, if you are trying to visually represent hundreds of thousands of points, quickly animate thousands of points, or create complex graphics that include 3D perspective computing, WebGL will be almost indispensable.

3.2. Ant approach to solving problems

The ant algorithm models a multi-agent system whose agents are called ants [28]. The ant approach is based on three components: a list of nodes passed, called the ant memory (tabu list); visibility, the value reciprocal of the distance between points; and the virtual pheromone trail on the rib. The implementation of this algorithm is based on an approach in which the probability of an ant choosing a specific route at each step is determined by the relation [29]:

$$P_{ij}(t) = \frac{F_{ij}(t)^a * N_{ij}^{\beta}}{\sum(F_{ik}(t)^a * N_{j}ik^{\beta}} \tag{1}$$

where $F_{ij}(t)$ is the number of pheromones on this route, $N_{ij}(t)$ is the length of the ij-th route, α and β are two adjustable parameters that specify the weight of the pheromone trail and visibility when choosing a route. When $\alpha = 0$, the nearest city will be selected, which corresponds to

the greedy algorithm in the classical theory of optimization. If $\beta = 0$, then only pheromone amplification works, which entails the rapid degeneration of routes to one suboptimal solution. The new pheromone value pheromone $F(t+1)$ on the path ij is calculated through the old $F(t)$ taking into account the pheromone evaporation coefficient b [13]: $F_{ij}(t+1) = b * F_{ij}(t) + \Delta F_{ij}(t)$ $\Delta F_{ij}(t) = \frac{Q}{K_n}$, where Q is an adjustable parameter, the value of which is chosen of the same order with the length of the optimal route (pheromone value), and K_n is the length of the path between the start and end points.

3.3. Software design

The developed software design consists of: a configuration file in which all application parameters are set (dimensions, grid colors, etc.); controllers working with the Main-Class (Grid, AntCanvas); systems; auxiliary scripts; the basic Main file working with HTML.

The visualization process works on a large number of ants (agents) and has the ability to change the number of these agents. Moreover, the system supports a frequency of 60 frames per second for a large (over 2 thousand) number of agents. The presented software product provides the user with functions that are accessible from the user interface, such as: building routes on the grid; storage / loading of routes; launch of ant colony optimization (ACO) algorithm and some of its modifications to the search on the grid; comparison of the results of various modifications of the algorithm in time and processor load; storage of reports and screenshots of algorithm.

In view of the fact that the main practical application of the presented method (application) is to find the shortest way for transporting or delivering an Internet package on the network, the user should be given the opportunity to reflect the algorithm on the graph. Since the graph is a combination of arcs and vertices, the basis for the graph is a fixed grid of vertices, and the user, to simplify the work with the application, will be able to build any graph by connecting these vertices arbitrarily. Limiting the user with a fixed grid, we lose the ability to make the graph flexible, but it provides an opportunity to make a visual analysis of the path length without software processing all possible connection options, since it will be more convenient for the user to determine the distance in a fixed grid.

Considering the analysis of all the possibilities of implementing animations in web applications and the fact that the grid is limited by the user's screen, SVG was chosen as the optimal technology. The application is resistant to actions that are not foreseen by the main functionality, and informs the user of a found error in a particular place and in a particular modification. The application architecture is as flexible as possible, which in the future gives developers the opportunity to create modifications to already implemented algorithms without wasting time on visualization.

3.4. Capacity assessment of the developed system

The designed application corresponds to the prototypes in design and functionality. The ability to control other parameters of the algorithm was additionally added. They are: the number of pheromones, evaporation, alpha and beta values (1), as well as the ability to hide the visual parts of the algorithm, if they are not needed. This can significantly speed up the program, especially

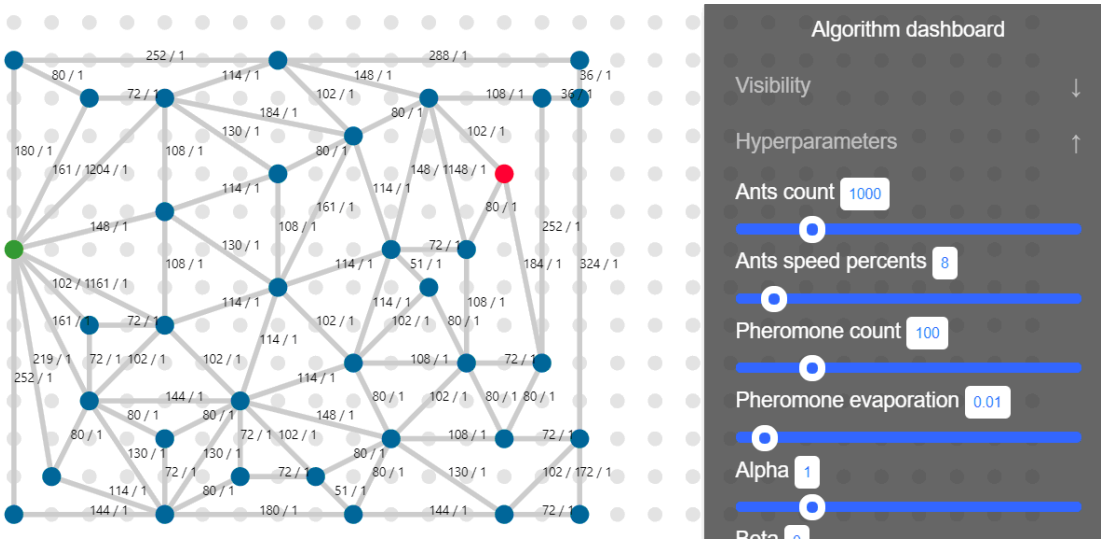

Figure 1: Example of routing task.

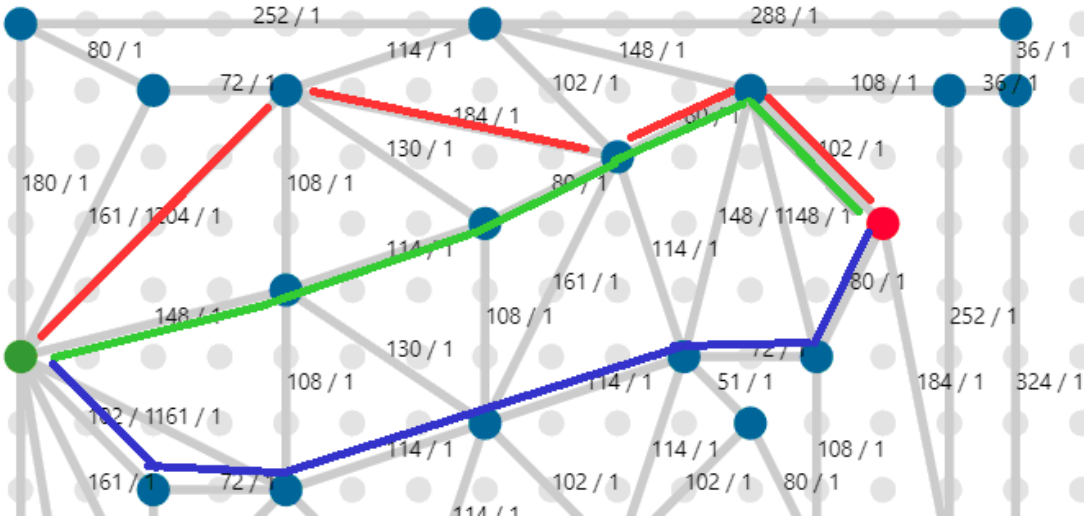

Figure 2: Solution of the routing problem. Red and blue are suboptimal solutions, green is an optimal solution.

if the user hides the drawing layer of ants. An example of the interface of the constructed program is shown in figure 1.

The constructed graph is designed so that the task for the ACO algorithm is not trivial. Figure 2 shows the optimal and two suboptimal solutions to the problem. Based on the approach proposed by Dorigo and Stützle [30], a modification of the obtained ACO algorithm is implemented. The results obtained make it possible to judge the optimal choice of parameters when solving the traveling salesman problem with various initial data.

In figure 3 presents the process of finding the optimal solution to the logistic problem. The

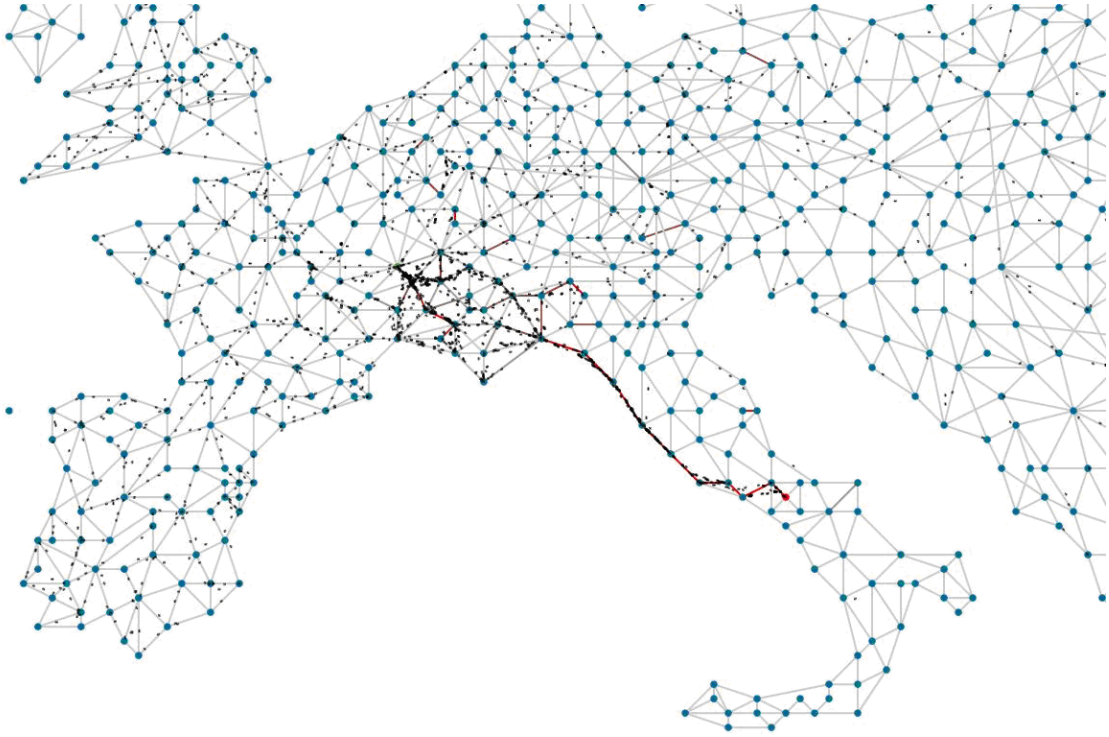

Figure 3: Visualization of the solution of a logistic problem.

created web application helps users better understand the ant algorithm.

Under the present study, a comparative analysis of the application operation and analogue program Simple ACO JavaFx was carried out. To optimize the developed application, passive evaporation was replaced by active one. Such a solution changes the evaporation system from linear to exponential, and pheromone values do not accumulate very quickly, as in a similar program. The results obtained showed that active evaporation is really more effective than passive evaporation; however, in this case, ants began to choose the lower (blue) route more often. It is worth noting that this route has one anomaly – it has the shortest arcs to the start and end points. Thus, it becomes clear that on this short route, ants release more pheromones, which makes the lower route more attractive. To address this problem, a dual strategy was applied to the determination of pheromones. Other than providing a local value, an ant will now remember the total distance covered, and on returning to the starting point, additional pheromone values will be determined by this distance. A comparative analysis of the above solutions is presented in the table 1. The resulting solution is effective in the use of large-scale graphs. The analysis was performed with the same value of ants (1000) and their speed. The comparative analysis of algorithms by value of the resources used in Windows Task Manager is presented in figure 4. The built application consumes 85% at the beginning and then 42% of CPU load, but a similar one consumes 100% at the beginning, and loses a lot in FPS value, and then 51%. Also, a similar program is much worse than the new one in terms of graphics resources: 18% vs 47%. Therefore, the developed solution is optimal from the viewpoint of

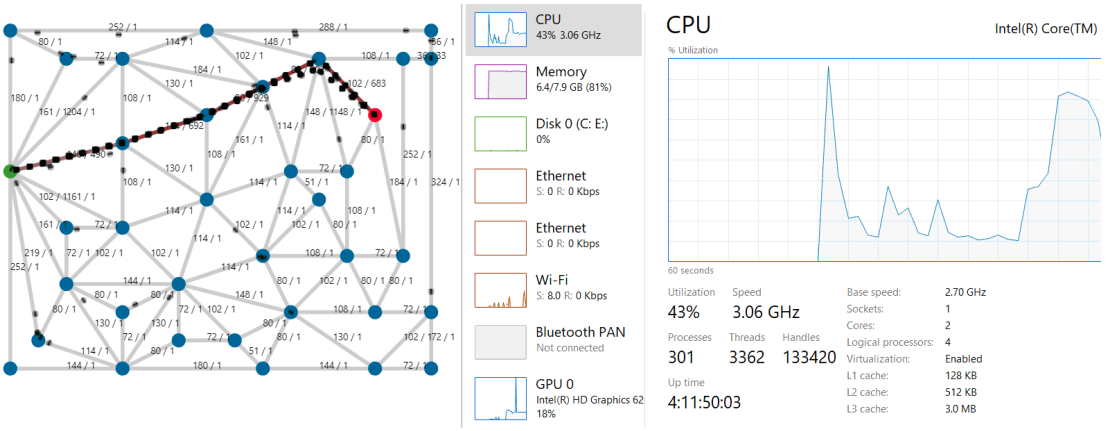

Figure 4: Use of computer resources for the built application.

system resources use and correctness of classical ant algorithms work.

Table 1
Relative amount of route selection by different programs based on 100 iterations.

	Upper route	Optimal route	Lower route	Other
Built application	7%	71%	18%	4%
Built application after modification	7%	80%	9%	4%
Simple ACO JavaFx	11%	61%	13%	15%

4. Results

The logistics system of an enterprise can be viewed from two sides. Its first important element is the efficiency of the interconnection of the transport system for the delivery of products built at the enterprise. On the other hand, a software product is of particular importance, using which you can train personnel both at the enterprise and implement it in the educational process.

The course “Transport logistics” is an integral part of the training of highly qualified specialists, both technical and economic specialties. Previously, this subject was taught according to the standard curriculum.Today, there are rapid changes in the existing operating conditions of transport companies, so enterprises need specialists who meet the existing high requirements. For this, it is necessary to introduce new practical methods into the teaching methodology of this discipline, which will strengthen theoretical knowledge with practical experience. Since in our time computerization covers all areas, it becomes necessary to strengthen practical training with the help of modern computer programs.Cooperation with employers in mastering the competencies of today’s students ensures, with the help of our professionals, an increase in the efficiency of the enterprises of the Ukrainian economy as a whole.

4.1. Methodical experiment

A methodical experiment, conducted even under artificially created conditions, is always a training one. The experimental work was carried out on the basis of the engineering institute of the Zaporizhzhia National University. The students of the technical (software engineering) and economic (accounting and taxation) specialties participated in the experiment. At the beginning, the testing was used to study and obtain feedback from stakeholders. Using special survey forms for testing, the desired changes of definite courses in the educational program in order to improve the quality of education were determined.

The survey highlights the need for taking into account the wishes of both employers and students, and also indicates the interest of all participants of the educational process in obtaining relevant competencies, a high level of knowledge and skills based on the learning outcomes. The analysis of survey forms showed that a free choice of disciplines is provided for building an individual educational trajectory for 100% of students. However, a survey of students revealed their desire to change the work program, namely: 30% of students feel the need to increase the number of practical examples, 50% of students want to solve specific tasks, that employers face, in practical classes, 20% of students want to try more other teaching methods in the lessons, 40% of students believe that the material will be better comprehended if during the lessons visualization of teaching methods is used.

After studying the first module by students of the indicated specialties of the corresponding educational programs in the framework of the studied disciplines, namely, “Mathematical Methods of Operations Research” and “Economic and mathematical modeling”, the results of a student survey were taken into account and changes were made to the structure of the discipline and its teaching methods.

For the reliability and purity of the experiment, the students were divided into two groups – the control and the experimental. At the second stage, a formative experiment was conducted. It made it possible to identify the pedagogical conditions for the better possibility of solving creative tasks that integrate the knowledge of various disciplines. In the control group, classes in the developed elective course were not conducted and students’ desire to solve creative tasks was formed spontaneously. In the experimental group, teaching of the orientation elective course was carried out to form a willingness to solve specific creative tasks arising from employers. Within the framework of the created complex of didactic support for disciplines, students of the experimental group were introduced to modern methods of presenting theoretical and practical material. For a better understanding and information comprehension, the application for visualization of the ant colony optimization algorithm was used as an example in the relevant topics.

At the third stage of work (the ascertaining stage of the experiment), a survey of the participants in the experiment was conducted. The research results of the quality of education, obtained on the basis of the developed survey forms, are presented in table 2. At the end of the study of relevant topics, students of both the experimental and control groups were tested in order to identify the level of assimilation of knowledge and skills for their integration in the study of various academic disciplines, as well as the ability to solve creative tasks.

After the second module, it was noted that in those groups where laboratory and practical exercises were conducted with the help of a visualizer, the knowledge, skills and ability to solve

Table 2
The results of a students survey of the experimental group regarding the quality of training in the educational program.

Survey of respondents interests	after first module	after second module
Providing interesting discipline teaching	80%	95%
The need for visualization teaching methods	60%	100%
Willingness to solve creative problems	70%	100%
Sufficiency of solving specific tasks arising from employers	50%	97%
Satisfaction with the quality of teaching the discipline	80%	100%

creative tasks were found to be 40–50% higher (for various parameters). The satisfaction of students with the sufficiency of the quantity of specific tasks set by employers was almost 50% higher in the experimental group. All students of the experimental groups were ready to solve creative tasks, at the same time, the number of such students in the control groups was about 70%. Thus, a change in the curriculum after clarifying the real needs of students made it possible to increase student satisfaction with the quality of teaching the discipline by more than 20%. In modern conditions, a survey of stakeholders showed how taking into account the opinions of students affects the quality of teaching the discipline and increases the level of students' learning. The results of the experiment emphasized the fact that the teacher conducting a regular survey of students, studying their opinions and, based on their needs, making changes to both their curriculum and the plan for conducting their classes, may create an integrated approach for maximizing the principle of student centrism. Only the orientation on students' interests and needs, provided by a timely survey, allowed us to improve the quality of education of both individual specialties and the educational system at Zaporizhzhia National University as a whole.

4.2. Analysis of the efficiency of the logistics system of enterprises

Based on the information provided by the State Statistics Service in annual statistical collections, we will analyze the transportation of goods by road and freight turnover of road transport in the regions of Ukraine for 2010–2019 (figure 5, 6).

By regions of Ukraine, road freight transport increased from 938.9 million tons in 2000 to 1147.0 million tons in 2019. The analysis of cargo transportation by road in 2019 showed a high demand for it in the regions of Ukraine, namely: Kyiv 51.5 million tons, Cherkasy 34.6 million tons, Kharkov 29.6 million tons, Odessa 28.8 million tons, Lviv 24.4 million tons, etc. However, the forecast of statistics on road freight transport may decrease in the future, due to the introduction of quarantine and periodic restrictions on trade in manufactured goods in stores and the operation of markets, which will reduce the purchase of goods by trade and entrepreneurs.

Meanwhile, in general, we see that the transportation of goods by road is in demand in all regions of Ukraine.

By regions, the freight turnover of road transport increased from 19281.6 million tons per km (tkm) in 2000 to 64952.9 million tkm in 2019. In 2019, the analysis of road transport turnover by

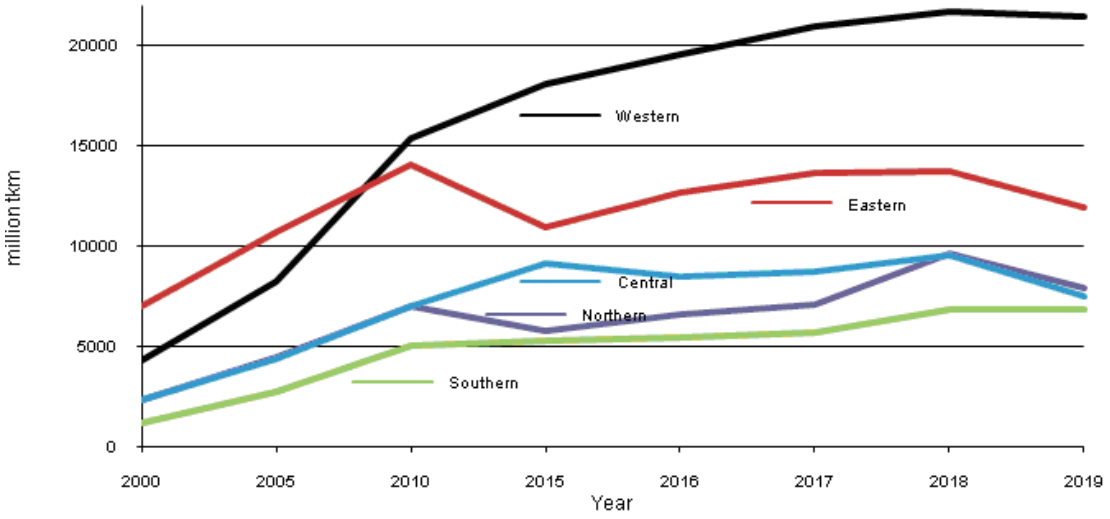

Figure 5: Freight turnover of road transport by regions.

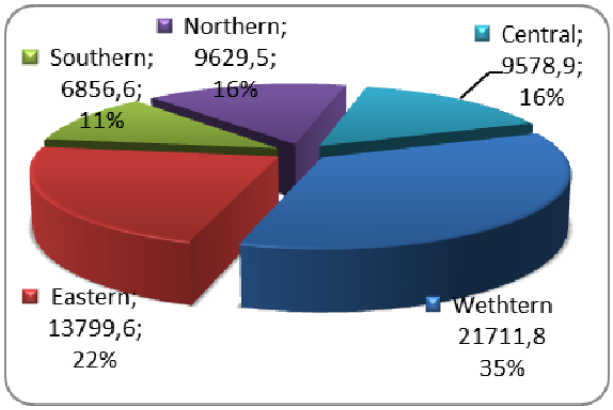

Figure 6: Freight turnover structure of road transport by region in 2018.

regions of Ukraine showed the following activity, namely: Lviv 5150.1 million tkm, Kyiv 4253.8 million tkm, Kharkov 3783.4 million tkm, Odessa 3693.5 million tkm, Cherkasy 2270.9 million tkm, etc. During all periods, there was an increase in the turnover of road transport, except for a slight decrease in 2019 compared to 2018. The structure of road transport turnover shows the following share by regions (directions of movement) of Ukraine, namely: western – 22%, northern – 16%, central – 16%, southern – 11%. Thus, as we see, the freight turnover of road transport has a significant impact on the economy of Ukraine, so an important issue is to build an efficient logistics system in the regions of Ukraine.

Profitability of operating activities as an integral indicator of the efficiency of the logistics system is calculated as follows: $Po = (Op/Gc + Ac + Sc + Oe) * 100\%$, where Po – profitability of operating activities; Op – profit from operating activities; Gc – cost of goods sold (works, services); Ac – administrative costs; Sc – sales costs; Oe – other operating expenses. Based on the

annual data on income, expenses and profit of the enterprise, which are given in the Statement of financial results (Statement of comprehensive income), we will calculate the integrated efficiency of the logistics system of Transport Company LLC (table 3).

Table 3
Calculation of the integrated indicator of the efficiency of the logistics system.

Indicator	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Integrated efficiency index of the logistics system, %	15.4	15.2	15.0	14.8	14.6	14.4	14.2	14.0	13.8	13.6	23.1

Analysis of the integrated efficiency indicator of the logistics system of Transport Company LLC for 2010–2019 showed that its indicator decreased from 15.4% to 13.6% every year. Therefore, in 2020, the program presented in the work was introduced, which increased the efficiency of the logistics system of Transport Company LLC by 1.5 times. Efficient construction of transport routes significantly reduced the cost of delivery of goods, which increased the efficiency of the logistics system and the company "Transport Company" in general. The developed program is universal, so its implementation is possible at transport enterprises, as well as at private enterprises and state institutions in the regions of Ukraine, which will increase their economic efficiency.

An assessment of the economic efficiency of logistics services can be made by calculating the indicator of the same name, reflecting the amount of logistics costs that are necessary to ensure 1% of the quality of service: $Le = Lc/Qs$, where Lc – logistics costs associated with the execution of a service order in the logistics system, UAH; Qs – the quality of logistics services, assessed by the degree of satisfaction of consumers' requests, %.

The assessment of the economic efficiency of logistics services of Transport Company LLC for 2020 showed an increase in its efficiency indicator by reducing logistics costs and improving the quality of service in the logistics system.

5. Conclusions

This article proposes a visualization of the ant colony optimization algorithm as a means of interactive teaching for students of various specialties in logistical tasks. The visualization includes:

- Graph construction
- Simulation of a dynamic network (adding and deleting a graph while running an algorithm)
- Visualization of the movement of a large number of ants
- Saving and loading a graph
- The ability to clean visible layers during algorithm operation for visualization simplification

A comparative analysis showed that with the correct algorithm construction, it is possible to achieve strong performance in choosing the optimal routes.

An experiment was conducted to verify the effectiveness of the use of visualization in achieving academic competencies. The results showed that:

- 40% of students believe that the curriculum should be changed to include more visualization teaching methods.
- Students in the experimental group had 40-50% higher skills and abilities to solve creative problems than students in the control group.
- Students in the experimental group were 20-30% more satisfied with the quality of teaching and the number of solved practical problems than students in the control group.

These results indicate that the use of visualization in teaching can have a positive impact on the educational process.

In conclusion, the use of interactive methods in the process of teaching engineering and economic specialties helps to optimize the educational process, increases the informative capacity of the material studied, and improves the efficiency of learning.

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