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RESEARCH ARTICLE

DEVELOPING A DECISION SUPPORT SYSTEM FOR EXAM SCHEDULING PROBLEM USING GENETIC ALGORITHM

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ABSTRACT

Exam scheduling is a very complex process done every semester in every educational institution and is usually done manually. The limited resources in these institutions make the preparation of the exam program a demanding and inconvenient task. In addition, when exam scheduling is examined in detail, it is seen that it is a comprehensive task that requires fulfillment of many situations other than the appointment of the appropriate course for the appropriate time period. In this study, a solution approach that allows the assignment of courses to time periods is proposed for the educational institution whose data we use. Thus, it is aimed to obtain a program that can quickly solve the exam scheduling problem, which is a comprehensive task for the educational institution. A Genetic Algorithm, an artificial intelligence optimization algorithm, was used as a solution method, and the performance of the method on the problem was tested. In addition, taking into account students, lecturers, and administrative staff's performance within the study's scope and purpose, it aims to obtain exam programs that will satisfy everyone. However, most studies focused on the solution to the problem, and the idea of making this program suitable for the use of non-technical personnel was neglected. The program we developed in this study has been turned into a decision support system. Thus, the program has become a structure suitable for the use of non-technical personnel. As a result of the study, considering the institution's entire structure, a program that the institution can use in every exam period was obtained, and the exam program was automated, eliminating the time and effort spent by the institution staff.

Keywords: Exam Scheduling, Genetic Algorithm, Decision Support System

1. INTRODUCTION

Education is the cornerstone of civilization that allows technological progress and is one of the most important steps to ensure species' survival. Education has been extremely useful and has taken different forms over generations. However, most importantly, education is responsible for all the developments and growth that is seen in the world today. Educated and intellectual people are an essential part of a workforce that keeps the world running and innovative. Education enables creative thinking and encourages the process of discovery and innovation. Therefore, education is regarded as one of the most basic human life requirements in the world, along with food, water, and other essential goods. [1].

Today, educational institutions have become highly organized structures operating with high efficiency. Every hour is used to convey and disseminate information as there is no waste of time. Due to the large-scale technological advances seen in recent years, many administrative tasks in educational institutions have been automated and computerized. This is a favorable improvement as it makes things easier and saves a lot more time to do other important tasks that require human intervention. However, one of the problems seen in educational institutions is that the scheduling of course and exam programs is not automated even today. This has to do with the many constraints governing the creation of the timeline [1].

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The scheduling problem is concerned with the allocation of these resources to meet all scheduling requirements. Scheduling is one of the important tasks encountered in real-life situations. There are various scheduling problems, such as personnel scheduling, production scheduling, transportation scheduling, training scheduling, etc. Educational scheduling is a difficult task due to the many constraints that need to be satisfied to achieve a viable solution. The educational scheduling problem is known to be NP-hard [2]. The educational time scheduling covers lesson scheduling and exam scheduling problems. The Exam Scheduling Problem (ESP) basically involves the allocation of a set of exams, supervisors, and classrooms for a specified exam time. It is necessary to schedule a large number of course exams in a limited and often short time. As a result, an exam schedule indicates which supervisor and student met, at which place, and when. Most of the research aims to develop methodologies that focus on producing the best quality timelines for a specific problem example. Due to the ESP's complexity, the researchers use heuristic methods such as Genetic Algorithm, Simulated Annealing, Tabu Search to solve the problem [20].

The Genetic Algorithm (GA), which is used to solve the problem in the study, was developed by John Holland (1975) throughout the 1960s and 1970s and later popularized by his student David Goldberg. GA is an optimization and search technique based on the principles of genetic and natural selection. GA enables a population of many to evolve into a state that maximizes “fitness” (i.e., minimizes cost function or maximizes profit) under specified selection rules [3]. GA, which is a type of random search algorithms, simulates the genetic development in living things. As in other evolutionary algorithms, the algorithm uses an initial population and applies the natural selection and reproduction processes upon generation within the population. Thus, more suitable solutions are started to be obtained, and the best quality solution in the last generation is determined as the most suitable solution for the problem [19]. It has been observed that the GA method gives successful results in the literature in solving many different problems such as robot applications, network design problems, image and voice recognition, artificial intelligence applications, and scheduling problems.

The structure developed after the solution of the problem is a Decision Support System (DSS). DSS is a subset of computer-based information systems. DSS can be defined as a decision-making system that provides computer-based human-computer interaction. A DSS consists of two main subsystems. The first is a decision-maker, the other is a computer system. Thus, it would be erroneous to represent DSS as just hardware and software because making unstructured and semi-structured decisions that cannot be programmed without a human being is unthinkable. The human decision maker's role is to provide and access data in these systems' databases and use his/her emotional and intuition abilities in the entire decision-making process. Within this study's scope, the manager responsible for the exam program chooses one of the different exam programs obtained with the program [21].

In the continuation of this chapter, the studies on this problem in the literature are mentioned, then the problem and the solution method are explained, and the performance of the method on the problem is explained in the next chapter. Finally, the study's results and contributions and what kind of improvements can be made to the current study in the future are mentioned in the conclusion part.

2. LITERATURE REVIEW

In this section, the studies that consider exam scheduling as a problem are summarized by considering what techniques have been used during the implementation phase, and then an overview of the method used in the literature on solving different problems and their transformation into a DSS is presented.

Duong and Lam (2004) presented a solution method for the exam schedule consisting of two steps: They used Constraint Programming and Simulated Annealing Algorithm to provide an initial solution [4].Sagir and Ozturk (2010) used the Analytical Network Process model to solve the problem by prioritizing to the aims of the examiner problem in their article. There are ten sets in the model. Criteria for all participants and their relationships are defined. The different objectives of the problem are dealt with alternatively in this model. Relative weights were obtained for the elements in the Analytical Network Process model using the Super Decisions software. The problem was then solved using these weights with a nonlinear optimization model developed previously with various constraints [5].

Yaldir and Baysal (2012) conducted a study on the preparation of the exam program. In the application phase, they used the GA method, which is an evolutionary calculation technique [6].

In their study, Anwar et al. (2013) proposed a Harmony Search-based hyper-heuristic method for the exam program scheduling problem. The proposed method has been tested using ITC-2007 comparison data sets [7].

Jha (2014) aimed to create an exam timetable using real student data in his article. A "GA" has been proposed as a method at the stage of creating the timetable [8].

Koide (2015) aimed to solve the problem of assigning an exam supervisor, which faculties regularly make in every exam period. In the study, a Mixed Integer Programming model is used to solve the problem. In addition, some solutions have been discussed to increase practicality for system users [9].
Woumans et al. (2016) studied the exam timeline problem and approached the problem from a student-centered perspective. They used two different Column Generation Algorithms to solve the problem in their work [10].

Dener and Calp (2018) addressed central exam scheduling problems of educational institutions as a problem. They developed a two-step algorithm in their study and used GA as a method. In the first phase of the algorithm, the courses were correctly assigned to the sessions, and in the second phase, the students participating in the exam session were assigned to the exam halls; and thus, it was aimed for the institutions to carry out their central exams successfully [11].

Cavdur et al. (2018), to create a balanced exam program, the credit, success rate, and type criteria of the courses and exam criticality levels were determined using Ward's method and k-means algorithm. An exam schedule was prepared using a Goal Programming model with these criticality levels. It has been observed that the obtained exam schedule has a balanced structure [12].

Tapkan (2019) developed a mixed-integer mathematical model for the final exam of the educational institution he was working on in his study and used the CPLEX 12.6.1 optimization package program to solve the problem. The final program obtained after solving the problem was compared with the research assistants' final program. In the final program obtained with the developed model, fewer classrooms were used than the other program, fewer linear supervisor assignments were made, classrooms were tried to be used with full performance, and an exam sequence was created that increased the student's performance [13].

Ceylan et al. (2019), developed a Goal Programming model for the ESP, and the optimization of the problem was done in the GAMS / CPLEX program. The data of the Ondokuz Mayis University Industrial Engineering Department were used. It was observed that the developed method gave better results when compared with the manual exam schedule [14].

Leite et al. (2019) proposed a new type of Simulated Annealing algorithm called FastSA to solve the ESP. Proposed FastSA and standard Simulated Annealing approaches have been tested on the 2nd International Timeline Competition (ITC 2007) benchmark set. The recommended FastSA in terms of solution cost and execution time has achieved better results in most instances. FastSA ranked third among the best five algorithms when compared with the most advanced approaches [15].

Dios et al. (2015) have developed a DSS for surgery planning in their studies, currently used in several Surgical Units in one of Spain's largest hospitals. This system has a structure that includes a series of optimization processes to support decisions regarding the assignment of operating dates and operating rooms for patients on a waiting list. The proposed DSS has an interactive graphical user interface and allows users to change plans for last-minute changes manually [22].

Poon et al. (2011) proposed a real-time production operations DSS to solve stochastic production material demand problems. In this system's problem-solving stage, the GA method was used. The real-time production and warehouse operations status was monitored using Radio Frequency Identification technology with this system [23].

Kandakoglu et al. (2020), in their study, working with doctors and managers from Ottawa Hospital in Canada, have developed a DSS that aims to assist managers of nephrology departments in creating daily visit schedules and routes for nurses helping patients with dialysis treatment at their homes. DSS used a Mixed Integer Linear Programming model to create daily nurse routes that minimize the cost of providing dialysis at home for a preset group of patients [24].

In Guler and Gecici's (2020) studies for Yildiz Technical University Industrial Engineering Department exam program, a Mixed Integer Programming model was proposed. The developed program has been turned into a DSS that does not require any technical knowledge and can be easily used by an average spreadsheet user [25].

In their studies, Chen et al. (2019) highlighted that a precisely timed irrigation program to meet crop water demand is vital to improving water use efficiency in arid farmlands. A real-time irrigation planning infrastructure was created, and DSS was developed for irrigation planning [26].

Bomsdorf and Derigs (2008) developed a model to solve the filmmaking planning problem in their work. Even a small movie project needs to be planned for different actors, teams, activities, and complex constraints. The DSS structure has been developed with an intuitive approach to plan a faster and better schedule [27].

Lin et al. (2014) stated in the study that in a dynamic environment where new customer orders of courier service and order cancellations arrive continuously over time, the optimum route program initially designed would be disrupted. Therefore the routes should be re-optimized in real-time. In this study, a DSS is proposed that optimizes dynamic courier routing processes that take into account new customer orders and order cancellations simultaneously. As the solution method of the problem, a hybrid local search algorithm integrated with DSS is used [28].

Ruiz et al. (2004) used a two-step solution approach for the vehicle routing problem. In the first stage, all viable paths are generated through an enumeration algorithm; then, in the second stage, an Integer Programming model was designed to select the optimum routes from the appropriate set of routes, and an interactive DSS was developed [29].

Kocsi et al. (2020), the aim of the studies is to develop a method that will minimize the total production process time by taking into account the risk analysis results of production in the Industry 4.0 environment. A hybrid approach has been proposed to solve the problem, and a real-time production scheduling DSS model has been developed [30].

Ko et al. (2010) conducted a study on an appropriate production planning problem to ensure effective resource utilization and developed a GA-based DSS to help production managers organize their production plans [31].

3. MATERIALS AND METHODS

This section describes the ESP first. Then, the details of the GA method used are presented.

3.1. Exam Scheduling Problem

ESP can be defined as scheduling a set of exams in a limited number of time frames or periods to meet a certain set of constraints as much as possible. Since this task is time-consuming and tedious, a much effort has been put into automatically creating timelines over the past few decades. With a large number of events to be assigned to resources (time slots and classrooms) and a constraint list (both hard and soft) to address, there are numerous potential solutions to this problem. What needs to be done in solving this problem is the use of limited time intervals and the classrooms without any conflict. A typical ESP includes both critical (hard) and non-critical (soft) constraints. Meeting all of these hard restrictions determines whether a particular program is applicable. However, the quality of an applicable timetable is determined by how soft constraints are provided [16] - [20]. Many of the constraints included in the ESP vary from institution to institution. The locations of hard and soft constraints for different studies may vary. According to the institution's structure and culture whose data is used in this study, hard and soft constraints are determined as follows. Different penalty points were given to these constraints according to their importance. Using these penalty points, the suitability of the individuals in the population, that is, the solutions for the problem was calculated during the problem-solving phase of GA. More detailed explanations are given on this subject in the following sections.

Hard Constraints
- No student can take more than one exam at the same time.
- More than one lecture of the lecturer cannot be assigned to the same session.
- A class cannot have more than three exams on the same day.
- The total number of students in the courses in a session cannot exceed the current classroom capacity.
- The exams for the courses common to different departments should be held on the same day and time.

Soft Constraints
- Each course should be assigned to the day and time requested by the lecturer, considering the lecturers' requests.
- The courses of any department's classes should be assigned to the exam schedule in a balanced way.
- According to the department's request, courses with high difficulty levels should not be assigned to the same day.
- Optionally, some departmental courses should be assigned sequentially.

3.2. Genetic Algorithm

Many people's invention was inspired by nature. GA method is one of them. GA is a search and optimization method based on natural selection mechanics and natural genetics, inspired by Darwin's evolution theory. GAs search by simulating evolution, starting with a set of solutions or hypotheses and generating sequential "generation" solutions. This particular branch of artificial intelligence is inspired by the way living creatures evolve into more successful organisms in nature. The main idea is that the fit ones survive and the others perish [17].

Genetic algorithms generally involve the application of selection, crossover, and mutation operators to a population of sequences. After the problem-specific coding in GA is made, the first population is formed, and the fitness value is calculated, it is time to apply the basic genetic operators to this population. Regardless of the initial solution, genetic operators provide better quality solutions in future generations. After the application of these operators, a new population is formed. The new population replaces the old population [18].

A simple genetic algorithm consists of five basic elements, each of which significantly affects the algorithm's performance. These parameters are; a representation of solutions, initial population generation, fitness or quality assessment function, genetic operators used, and control parameters [19].

Basic Concepts Gene: In GA, the smallest structural unit that carries genetic information on its own is called a gene. By combining these small structures, a complete chromosome (individual) solution is created. In the solution process of a problem using GA, gene structures depend on the defined problem variables [34]. The genes of two different chromosome structures are shown in Figure 1.

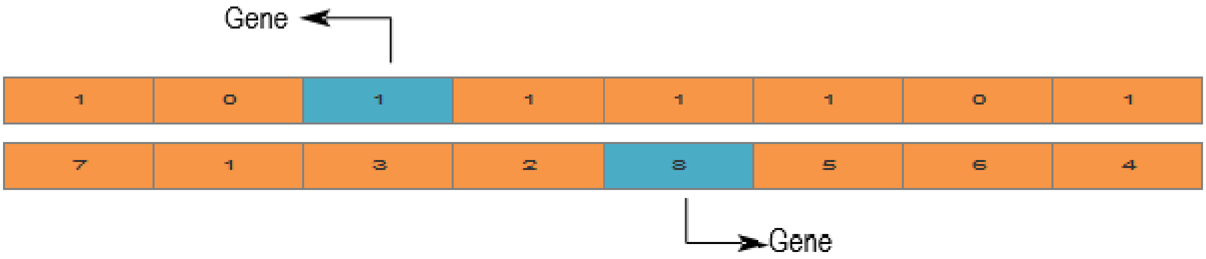

Figure 1. Gene display

Chromosome (Individual) : One or more gene structures come together to form a chromosome, and the chromosome contains all the information about the solution to the problem. A population formed by the combination of chromosomes is formed. Each chromosome is also called an individual of the population. Each individual represents a solution to the problem [34]. Figure 2 shows different examples of chromosomes.

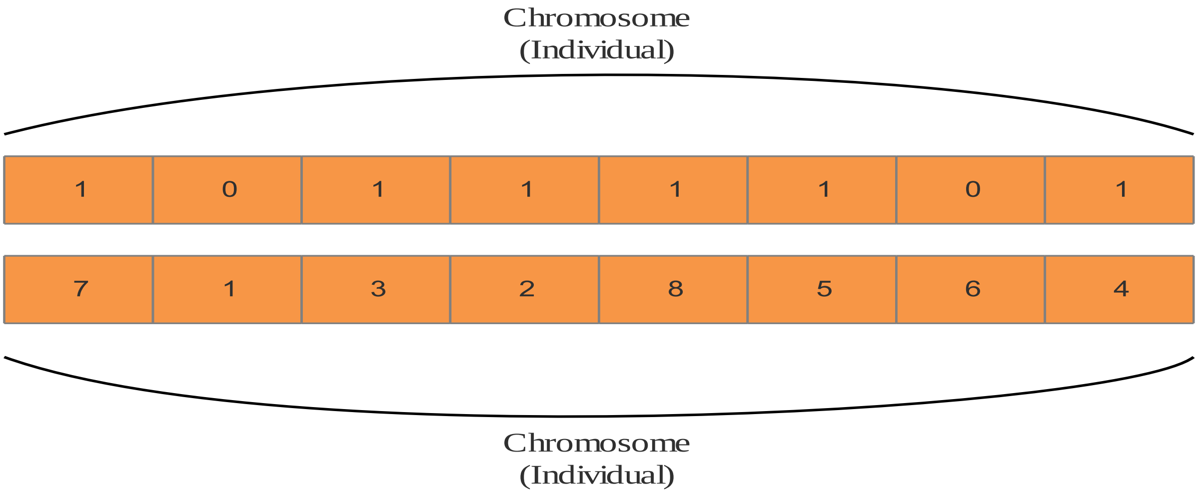

Figure 2. Chromosome representation

Initial Population: Initially, many solutions are randomly generated to generate the initial population. This first population is called the starting population. The number of individuals in the population is determined before running the algorithm. In the literature, different recommendations have been made for the number of individuals in the population. However, the size of the population is highly correlated with the nature of the problem. It is difficult to determine an appropriate population size for each problem. Figure 3 shows the population example.

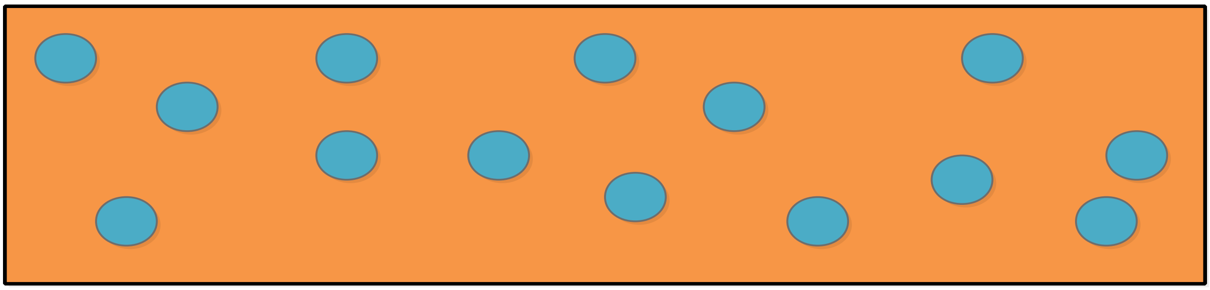

Figure 3. Population sample

Fitness Function: The fitness function determines how appropriate each individual, that is, each solution, for the solution of the problem within the population created. The determination of the fitness function is the most important factor affecting the effectiveness of GA. The possibility of a fitness function that is not properly determined can extend uptime and even lead to a solution never being reached. Because in each iteration, the direction of the algorithm is determined by the fitness function [35]. The algorithm steps used by the GA method to solve the problem are as follows.

The basic steps of a simple GA [19]:

Step 1: Generate initial population, initialise random population.

Step 2: Calculate the fitness value of each solution in the population.

Step 3: Stop if the termination criteria are met.

If not, perform the following steps.

3.1. Apply the natural selection process (solutions with higher fitness values are more represented in the new population).

3.2. Apply the crossover process (two new structures are generated from two existing solutions)

3.3. Apply the mutation process (Random change in Solutions is created).

Step 4: Go to step 2.

Genetic Operators: Inspired by biology, three basic genetic operators are used to solve the problem. These are the selection operator, the crossover operator, and the mutation operator.

Selection Operator: One of the most important operators of GAs is selection. The selection operator gives priority to individuals with higher fitness value. Individuals with better fitness values in the population will be more likely to be selected. Therefore, with this operator, fitter individuals are allowed to survive for the next generation. Individuals obtained by the selection operator are called parent individuals. There are different types of selection operators in the literature, such as Roulette Wheel, Tournament, and Sequential. Here, the way Roulette Wheel and Tournament methods work is mentioned. How Roulette Wheel Method works; the fitness values of the individuals in the population are added. Afterwards, each individual's fitness value is divided by the total fitness value, and the probability of being selected is obtained. The selection process is made according to these possibilities. An example of this is shown in Table 1 and Figure 4. For this example, the higher the fitness value, the more likely the individual will be selected. In Tournament Method, from the individuals within the population, random individuals will be taken as many as the number of individuals to enter the tournament determined before the algorithm starts. Recruited individuals will be entered into the tournament among themselves, and the individual with the highest fitness value will be selected. An example of this method (the number of individuals entering the tournament is determined as 3) is shown in Figure 5. [32].

Table 1. Roulette wheel method

Individuals	Fitness Value	Selection Probability	Selection Probability (%)
Individual 1	720	720/3000 = 0.24	0.24
Individual 2	630	630/3000 = 0.21	0.21
Individual 3	390	390/3000 = 0.13	0.13
Individual 4	540	540/3000 = 0.18	0.18
Individual 5	240	240/3000 = 0.08	0.08
Individual 6	480	720/3000 = 0.16	0.16
Total	3000		100

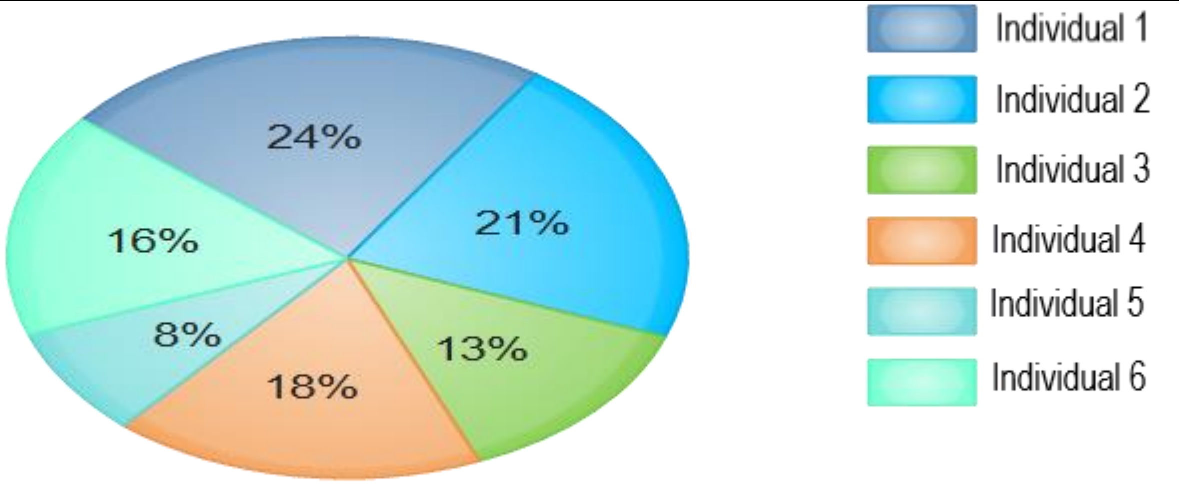

Figure 4. Roulette wheel pie chart

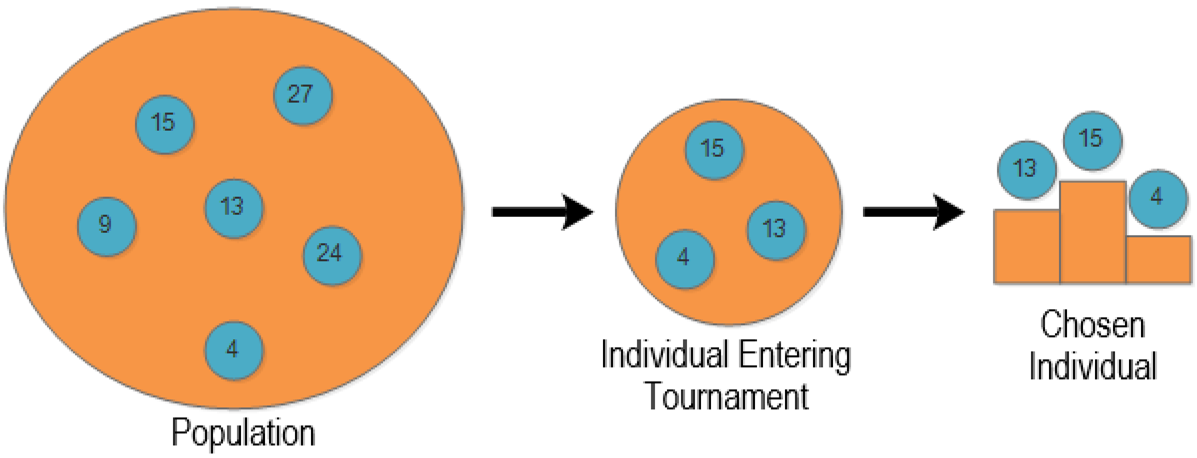

Figure 5. Tournament selection method

Crossover Operator: Parent individuals determined by the selection operator pass the crossover stage. At this stage, the crossover operator is creating child individuals by exchanging genes between parent individuals. Thus, it is aimed to create fitter individuals for the next generation. There are many crossover methods used in the literature. The selection of these methods is closely related to the chromosome structure representing the solution. Figure 6 shows an example of the crossover operator for two different chromosome structures.

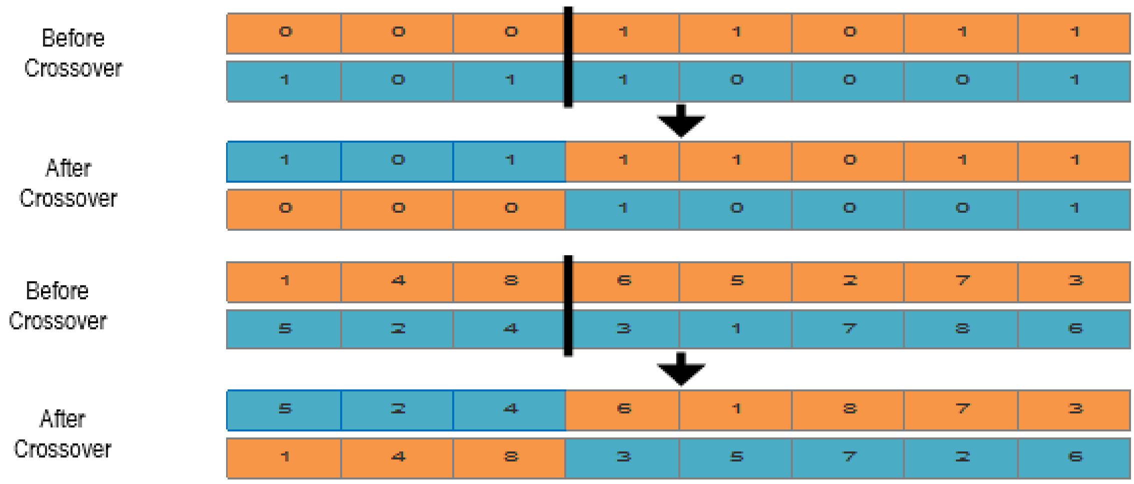

Figure 6. Crossover operator

Mutation Operator: In GA, the mutation process is applied to individuals after crossover. The mutation process is carried out as a random replacement of some chromosome genes with a certain probability. In this way, conservation of genetic diversity and as a result of this, local maximum or minimum can be avoided. As in the crossover operator, there are different methods in the literature for the mutation operator, and attention is paid to the determined chromosome structure as to which method to use [33]. An example of the mutation operator is shown in Figure 7.

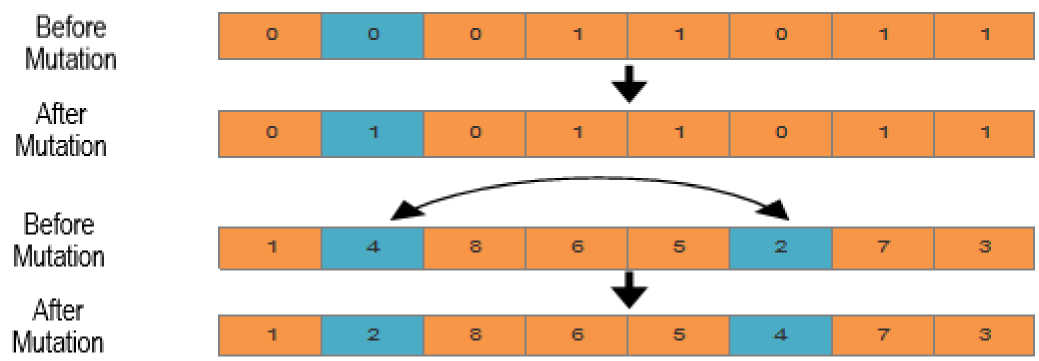

Figure 7. Mutation operator

3.3. The Solution of the Problem

This ESP's solution was started by transferring the course information for the exams to the Excel program. Only some common courses and courses taught in the form of distance education (Atatürk's Principles and Revolutions, Turkish Language, and English) are excluded from the model. Some time periods for those courses were closed, and the courses were assigned directly to those periods. This is provided with a constraint. The way this constraint works; if a different course is assigned to the time periods determined for these courses, it takes place by assigning penalty points to the fitness value of the solution. The general form of the data in the excel file is given in Table 2 below.

Table 2. Exam schedule data

Course No	Course Name	Classroom No	Program	Student Number	Department No	Instructor No	Difficulty General	Difficulty Branch
1	Inventory and Balance	1	Management	200	1	14	1	1
2	Financial Statement Analysis	1	Management	174	1	14	0	0
3	Administration and Organization	1	Management	169	1	25	0	1
4	Business Mathematics	1	Management	206	1	13	1	1

When starting the solution of the problem, the method takes the course numbers from the excel file to the Matlab program and creates the starting population with the course numbers taken. The structure of individuals within the population is in the form of a 10 * 30 matrix consisting of 10 rows and 30 columns. The row represents the weekdays of the two weeks (the days when the exams will be held), while the columns represent the time periods (09.00, 10.10, 11.20, 13.30, 14.45, 16.00). There are six time periods in total and each of these periods represents five columns. The matrix has a total of 300 cells, and the lesson numbers are randomly assigned to these cells. In cells with a value of 0, it means that there is no exam in that time period that day. An abbreviated example of an individual within the population is shown in Figure 8. All rows (days) are shown in the example, but not all columns (time periods) are shown If we give an example from Figure 8; in the first week, on Monday at 09:00, there is only the exam for lesson number 35.

Table 3. Individual structure of the problem

Time / Day	09.00	09.00	09.00	09.00	09.00	10.10	…
Monday	35	0	0	0	0	70	16
Tuesday	0	0	12	21	0	0	0
Wednesday	91	0	0	0	0	0	29
Thursday	46	0	25	0	0	88	32
Friday	20	0	60	0	0	0	0
Monday	0	0	0	0	0	9	33
Tuesday	39	2	0	55	0	0	0
Wednesday	0	0	0	0	45	0	90
Thursday	65	0	16	0	0	100	0
Friday	75	0	13	14	0	0	11

After the population was created, the fitness value of the existing individuals was calculated. This calculation was made as a penalty system using constraints. For each hard and soft constraint determined, a penalty score was given according to their severity. It is looked at how far each individual in the population has violated the constraints, using the fitness function. The penalty score of the constraint that an individual violates is added to its fitness value. The lower the fitness value of an individual, the better its suitability for problem solving. Calculation of the individual's fitness value is shown below.

$$f(b) = \sum_{j=1}^{n} Cj$$

b = Individual
f (b) = fitness value of the individual
n = Number of Constraints
Cj = j. Penalty of the constraint

The fitness value calculation process is repeated in every iteration. In Figure 9 below, the change in fitness value experienced within the population according to the increasing number of iterations is shown. The most suitable value in the population is shown in red, and the average fitness value of the population is shown in blue.

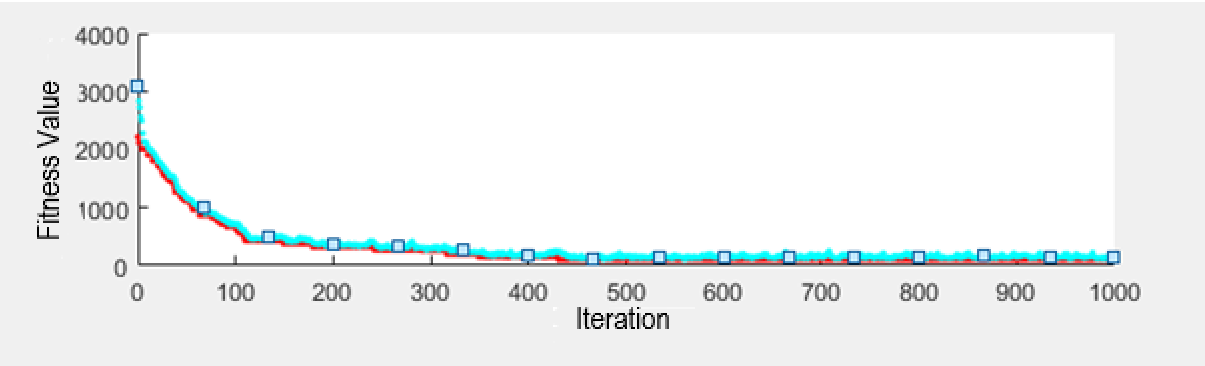

Figure 8. Fitness value change

After calculating the fitness values, the selection, crossover, and mutation processes, which are the three main GA operators, were applied to individuals. Trials have been made with the roulette wheel and tournament methods as the selection operator. Fit values were obtained by both methods. A method suitable for our chromosome structure has been preferred for crossover. The crossover was performed from two randomly determined points, and individuals with deterioration were corrected with the repair process. The repair process is used to prevent the loss of the chromosome's genes after the crossover or to prevent situations such as having more than one of the same gene. An example of the crossover we used is shown in Figure 10. A part of our chromosome is shared in our example.

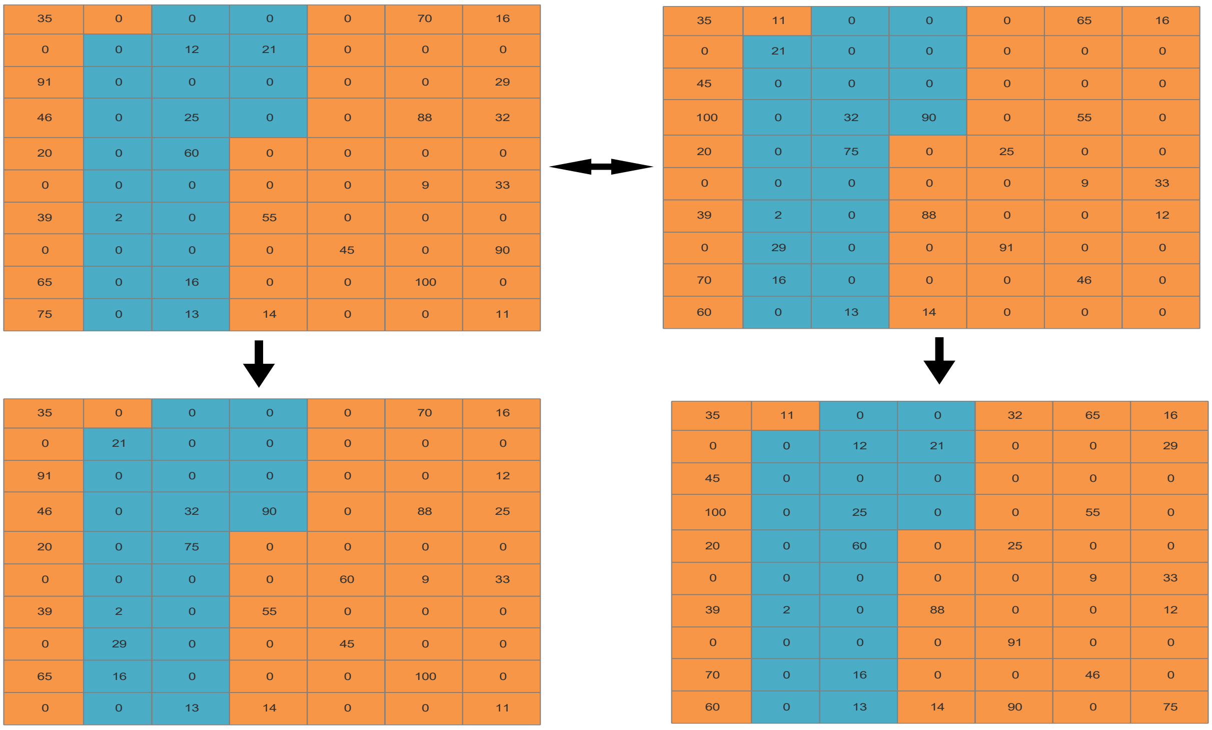

Figure 9. Crossover example

Finally, a standard mutation method was used for the mutation process. The places of the genes at two randomly determined points were changed. An example of the mutation we used is shown in Figure 11.

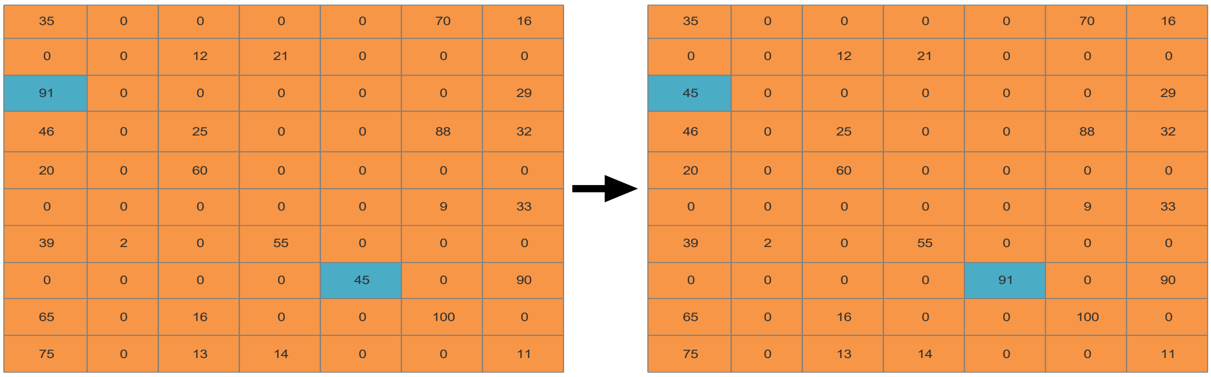

Figure 10. Mutation example

Appropriate results have been obtained for our problem with different parameter values. The GA suitable parameter values we use for the problem always give satisfactory results. The program's selection to be used among the obtained exam programs is left to the manager's decision. A system has been established where the administrator can see the final version of each exam program. With this system, the administrator will be able to run the program, obtain suitable exam programs, and use an exam program s/he wants by seeing the latest versions of these programs. A part of the final exam schedule is shared in the example in Table 3.

Table 3. Exam schedule

Day	Time	Course	Department	Year	Number
Tuesday	11:20	Public Relations	Public Administration	3	77
Tuesday	11:20	History of Economic Thought	Economy	3	81
Tuesday	13:30	Introduction to Management	Economy	1	100
Tuesday	13:30	Financial Statement Analysis	Management	1	174
…	…	…	…	…	…

4. CONCLUSION

For this study, Hatay Mustafa Kemal University Faculty of Economics and Administrative Sciences' actual data were used. An excel file is used as a database for data. Matlab program was used to solve the problem. The exam schedule is prepared by the assistants of each department in our faculty. The exam schedule from all departments is combined. Afterwards, it is finalized with the control of the officer and the manager. With this study, this gradual and long process has been eliminated, and a flexible system that can be used by the educational institution at all times has been created. However, a DSS has been developed for the administrator to use this program. GA and similar algorithms used as the method of the study do not guarantee an optimal result due to their nature. Instead, they achieve near-optimal results within a reasonable time. As a result of the tests performed on the GA method we prepared for this study, it was seen that the method obtained appropriate solutions. In this way, managers or officers who do not have technical knowledge will be able to run the program and obtain more than one suitable exam program in a short time and will be able to choose the one they want to use. Depending on his/her request, s/he will be able to make small changes on the exam program s/he has chosen or can use it directly. In the continuation of this study, it is planned to develop a 3-step algorithm structure by including the solution of the supervisor assignment and class assignment problems in addition to the solution of the ESP and to transform it into a DSS. However, in future studies, it is considered that the algorithm, which can be easily adapted to solve different problems, will be used in solving different real-life problems. At the method point, it is planned to carry out studies on genetic operators in order to increase the performance of the algorithm and to compare the performance of these methods on the solution of problems by using different artificial intelligence methods. In addition, studies on the subject of hybridizing the artificial intelligence methods that researchers have been working in recent years and testing them in solving problems are being considered. These planned considerations will form the basis of our future work.

CONFLICT OF INTEREST

The authors stated that there are no conflicts of interest regarding the publication of this article.

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