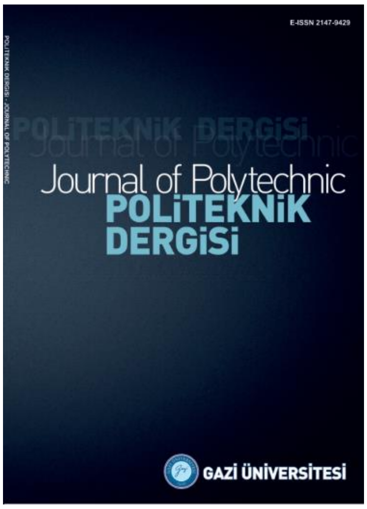

POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.org.tr/politeknik

Conference scheduling with epigenetic algorithm

Epigenetik algoritma ile konferans çizelgeleme

***Yazar(lar) (Author(s))**: Ercan ATAGÜN[1], Serdar BİROĞUL[2]*

ORCID[1]: 0000-0001-5196-5732

ORCID[2]: 0000-0003-4966-5970

Bu makaleye şu şekilde atıfta bulunabilirsiniz(To cite to this article): Atagün E., Biroğul S., “Conference scheduling with epigenetic algorithm”, ***Politeknik Dergisi***, *(*): *, (*).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: 10.2339/politeknik.1010504

Conference Scheduling with Epigenetic Algorithm

Highlights

- *The Epigenetic algorithm was coded using the genetic algorithm.*
- *The conference scheduling problem was solved on a topic-based basis.*
- *The Epigenetic algorithm is proposed for the scheduling problem.*
- *The Epigenetic algorithm produced better results than the Genetic algorithm.*
- *It has been proposed for the optimization problems of the Epigenetic algorithm.*

Graphical Abstract

The Multidisciplinary Conference Session Scheduling problem was solved by using the Epigenetic Algorithm.

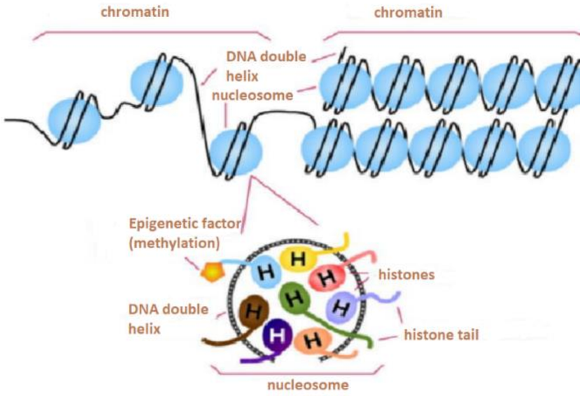

Figure 1. Epigenetic Mechanisms

Aim

Optimization of the conference scheduling problem with the help of Epigenetic Algorithm.

Design & Methodology

Hybridizing Genetic Algorithm with Epigenetic Algorithm design and designing according to scheduling problem Coding in Visual Studio using C# programming language.

Originality

The Epigenetic algorithm was coded using the genetic algorithm. The conference scheduling problem was solved on a topic-based basis.

Findings

The Epigenetic algorithm is proposed for the scheduling problem. The Epigenetic algorithm produced better results than the Genetic Algorithm.

Conclusion

It has been proposed for the optimization problems of the epigenetic algorithm. The Multidisciplinary Conference Session Scheduling problem was solved by using an Epigenetic Algorithm.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conference Scheduling with Epigenetic Algorithm

Research Article

Ercan ATAGÜN*, Serdar BİROĞUL

[1]Düzce University, Faculty of Engineering, Computer Engineering Department, Turkey

(Geliş/Received : 16.10.2021 ; Kabul/Accepted : 25.04.2022 ; Erken Görünüm/Early View : 27.06.2022)

ABSTRACT

The most important of the activities where the presentations of scientific studies take place are academic conferences. The days, halls, and sessions are determined in advance to organize multidisciplinary conferences and this process is called conference scheduling. In multidisciplinary conferences, in the scheduling of presentations, the coexistence of studies belonging to the same fields in the same sessions is very important for the conference listener and the conference speaker. In this context, the multidisciplinary conference scheduling problem is considered a multi-constraint optimization problem. Multi-constraint optimization problems are solved with heuristic optimization techniques, not traditional optimization methods. In this study, the problem of conference scheduling is addressed using multidisciplinary conference data. The solution to the conference scheduling problem was realized with Genetic Algorithm (GA) and Epigenetic Algorithm (EGA) using C# programming language. In the study, experimental results obtained with GA and EGA were examined. As a result of this examination, it was seen that EGA achieved better results in fewer iterations compared to classical GA.

Keywords: Genetic algorithm, epigenetic algorithm, conference scheduling.

Epigenetik Algoritma ile Konferans Çizelgeleme

ÖZ

Bilimsel çalışmaların sunumlarının yapıldığı etkinliklerin en önemlileri akademik konferanslardır. Multidisipliner konferanslar düzenlemek için günler, salonlar ve oturumlar önceden belirlenir ve bu sürece konferans çizelgeleme denir. Multidisipliner konferanslarda, sunumların planlanmasında aynı alanlara ait çalışmaların aynı oturumlarda bir arada bulunması konferans dinleyicisi ve konferans konuşmacısı için çok önemlidir. Bu bağlamda multidisipliner konferans planlama problemi çok kısıtlı bir optimizasyon problemi olarak görülmektedir. Çok kısıtlı optimizasyon problemleri, geleneksel optimizasyon yöntemleriyle değil, sezgisel optimizasyon teknikleriyle çözülür. Bu çalışmada, multidisipliner konferans verisi kullanılarak konferans planlaması sorunu ele alınmaktadır. Konferans çizelgeleme probleminin çözümü Genetik Algoritma (GA) ve Epigenetik Algoritma (EGA) ile C# programlama dili kullanılarak gerçekleştirilmiştir. Çalışmada GA ve EGA ile elde edilen deneysel sonuçlar incelenmiştir. Bu inceleme sonucunda EGA'nın klasik GA'ya göre daha az iterasyonda daha iyi sonuçlar elde ettiği görülmüştür.

Anahtar Kelimeler: Genetik algoritma, epigenetik algoritma, konferans çizelgeleme.

1. INTRODUCTION

Academic conferences are an indispensable element in the welfare and development levels of developed and developing societies. Scheduling problems are addressed as a topic of study in numerous conferences. The International Automated Planning and Scheduling Conference (ICAPS) first emerged as a scheduling-themed conference. ICAPS has enabled the development of many new algorithms [1]. The main purpose of conferences, which are scientific activities, is to produce information and to ensure knowledge sharing. During the sharing of information, research results and experiences are shared, enabling both the audience and the speakers to gain information. In his study, Aktay [2] observed that conference participants focused on factors such as the conference program, presentations, accommodation facilities, participation fees, and important dates. Andlauer et al. state in their study that there is a need for scientific, organizational, and humanitarian skills. Relevant committees should be established for the size and duration of the conference and the threads should be defined. The scientific board should be established and the theme of the conference, programs, sessions, and session chairs should be defined [3]. Nicholls proposed a heuristic scan that enables small and medium-sized conferences to be planned by the session chair. In the study, an overlap of authors was prevented with the heuristic scanning method. In addition, a reservation system has been applied considering some preferences of the participants [4]. Potthoff and Brams discussed the integer programming conference scheduling problem. The Public Choice Society and its conferences held in New Orleans in 2005 and 2006 were assigned to the specified time frames. Papers divided into subjects were divided into groups of 3 or 4 and carried out with the help of integer programming following the specified constraints [5].

---

*Corresponding Author

e-posta : ercanatagun@duzce.edu.tr

It was suggested that the presenters should not be allowed to make more than one presentation. In addition, when there is more than one paper, it has been recommended to prevent this situation in a deterrent way by taking more fees. The proposal to provide only one paper to one person during a conference has not yet been accepted. Participants requesting reservations make it difficult to solve the scheduling problem. In this case, speakers may want to make a presentation at certain periods such as the first day, last day, and last session. This situation may be penalized with an additional fee because it causes avoidance of optimum solution unless a special reason is required. Zulkipli et al. assigned the papers to be presented to the timeframes which are determined for conference scheduling problems. He ensured the settlement of the papers by addressing the conference capacity with the method they call the Goal Programming model. With the proposed model, a solution was produced by taking the restriction capacity as the main factor [6]. Eglese and Rand proposed a heuristic method for conference scheduling, including simulated annealing. Before the conference scheduling, the participants of the conference were expected to select the sessions they would like to attend with the help of a questionnaire [7]. In his study, Ibrahim et al. focused on parallel sessions to solve the problem of conference scheduling. They proposed a combinatorial design model in which three parallel sessions could take place. Based on this design [8], it has been defined as including solution proposals containing sub-sets in subsets. Sampson and Weiss proposed scheduling to increase conference attendance in their study. Emphasizing that no constraints are determined with linear programming and taking into account participant preferences, they proposed [9] a model that helps the conference organizing board. Sampson addressed the preference-oriented conference scheduling problem in his study. He stated that satisfaction increased in the sessions prepared by choosing the conference sessions from the same topics [10]. Thompson proposed a computer program to schedule concurrent sessions in his study. Considering the complexity of scheduling the conference he wanted to organize in his study [11], he proposed an algorithm that he called a special heuristic-based computer algorithm. Bhardwaj advocated the conference scheduling approach by considering the preferences of the conference organizing board, participants, and authors to present papers together [12]. Tanaka et al. proposed a study aiming to include the keywords in the paper to be presented at the conference in compatible sessions. In his study, he created a feature vector representing keywords and assigned the presentations of individuals to appropriate times and locations using the self-organizing map [13]. Mori and Tanaka emphasized that they achieved this situation with the Grouped Genetic Algorithm, which will enable similar topics to be found in the same session [14]. However, other constraints optimized in the study were not shared. A solution proposal including the scheduling of conference presentations and sessions was realized with the Integer Programming model. With the study, it is ensured that the topic titles of the sessions are formed and the presentations are placed under these topic titles. Two main constraints were taken into account in the study [15], such as not having a speaker in more than one session simultaneously and minimizing the number of presentations with sessions in the same time frame during a day. Stidsen and his colleagues have scheduled EURO-k conferences, which are among the largest Operational Research Conferences in the world. For the scheduling, the studies collected first are categorized according to their topics, with similar topics together. Mixed Integer Programming has been used as a solution model [16]. Correia et al.[17] scheduled Brazilian OR conferences that lasted 3 or 4 days and had approximately 300 presentations. They developed a method for the scheduling problem by combining iterative local search and simulated annealing algorithms. Bulhões et al. [18] proposed a clustering-based approach to the conference scheduling problem. Since the conference programs developed differently for each conference, it was emphasized that they should be formulated with a common purpose and the conference, which included 163 presentations, was scheduled. In the study, three mathematical formulations based on integer linear programming are proposed for the conference scheduling problem. Doshi et al.[19] have developed an application called StickySchedule, stating that it is insufficient to use whiteboards instead of sticky notes for the conference scheduling problem. This application organizes conference data and offers a multi-user design with interactive screens. They demonstrated the importance of scheduling the conference, taking into account the user interaction with the application they developed. Castaño et al.[20] proposed a content-based method for the conference scheduling problem. The method includes a two-stage approach. In the first stage, presentations are grouped according to their speech content. The second stage is aimed at listing similar contents one after another. Eltayeb and Ahmed [21] proposed a Hyper-Heuristic Approach for the conference scheduling problem. It is aimed that the sessions assigned to periods and rooms are planned and individual conflicts are avoided. It has been observed that the GR-AM algorithm for small conferences and the TS-IE algorithm for large conferences give good results.

1.1. Problem Definitions

Conferences provide gains such as information sharing, problem-solving, and explanation of the solved problems. Information sharing and dissemination are ensured by exchanging ideas at conferences. More efficient results can be obtained by providing two-way communication between speakers and listeners at conferences. The main factor in organizing academic conferences is the development of new knowledge, the promotion of knowledge, and the encouragement of learning through research [22]. Supported by academic conferences, universities, and research institutes contribute to the emergence of new information, enrichment, and updating of knowledge [23].

For the conferences to take place, the presentations are sorted by determining the days, places, and times in advance. After determining the day and time of the conference, the location of the conference should be determined. Conference locations usually consist of halls. To make speeches in the halls, many technical pieces of equipment should be provided. In addition to these technical pieces of equipment, it also requires the necessary human resources to keep these pieces of equipment running smoothly throughout the conference. Inefficient conference scheduling results in inefficient use of all these resources that will be used for the conference.

The number of conferences organized around the world is increasing day by day. At the same time, the participation in the conferences held reaches remarkable levels. Considering the increase in the number of participants, the participation of experts in the field, the expenditures of the events and services provided, and the gains that the conference offers to society and the scientific world, it is important to hold conferences efficiently. In this respect, the conference scheduling problem emerges as an important problem. Academic conferences usually cover a variety of presentations. Sessions refer to presentations made without rest between two breaks. There are usually 5 presentations in a session. At the end of a session, there is a break ranging from 10 minutes to 30 minutes.

Scheduling of conferences is carried out by automation, and without overlapping the sessions of the speakers, the relevant sessions are assigned per the desired conditions for all sessions by ensuring the integrity of the subject. Manual schedules will be very difficult and also difficult to modify. If every change causes another change on one side of the schedule, it will restart the control process. When all these problems are considered together, conference scheduling using computer software is manageable, sustainable, less costly, and more flexible. Good scheduling requires avoiding all undesirable situations.

Penalty points are calculated specific to all constraints defined in constrained optimization problems.

$$\mathrm{C} = \sum_{a=0}^{x} \sum_{b=0}^{y} \sum_{c=0}^{z} Pa * Cbc \qquad (1)$$

For x, y, z, a, b, c it should be:

$0 \leq x < \infty, 0 \leq y < \infty, 0 \leq z < \infty, 0 \leq a < \infty, 0 \leq b < \infty, 0 \leq c < \infty$ The fitness value is as follows:

$$Fv = \frac{1}{\sum_{a=0}^{x} \sum_{a=0}^{y} \sum_{a=0}^{z}} \quad -\infty < x < \infty \qquad (2)$$

*y = number of chromosomes z = number of genes, x = number of constraints, Cbc = b. C the gene in the chromosome with penalty value. Gene, Pa = a. penalty value of to the constraint.

If a conference scheduling problem is to be generalized, it can be defined as:

$$\prod_{\mu=1}^{\theta} \mu \qquad (3)$$

$$1 < \mu < \infty \; ve \;\; \mu \, \epsilon \, Z$$
$$1 < \theta < \infty, \quad \theta > \mu \; ve \; \theta \, \epsilon \, Z$$

µ: number of papers processed, θ: total number of papers

In this study, several constraints have been put forward for the conference scheduling process to reflect the actual field of application. Constraints are divided into two parts hard constraints and soft constraints. Hard constraints are determined as follows:

An author cannot be in more than one session at the same time.

All papers in a session must belong to the same primary category.

All papers in a session must belong to the same secondary category.

Soft constraints are determined as follows.

There should be no free spaces in a session.

All papers in a session must belong to the same tertiary category.

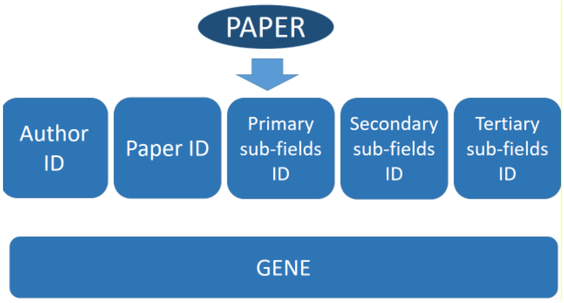

Figure 2. Production of the gene

Figure 2 shows the gene production that occurs when a paper is registered to the system. Thus, all papers accepted to the conference are expressed by a gene and both Genetic Algorithm and Epigenetic Algorithm become applicable.

2. MATERIAL and METHOD

2.1. Genetic Algorithm

GA is an algorithm proposed by John Holland and based on modeling the evolutionary processes of living things [24]. The evolutionary processes of living things are the protection of good individuals for their own lives and the extinction of bad individuals. GA is a heuristic algorithm that tries to generate solutions using random search techniques. It is based on the principle of parameter coding. Holland's doctorate student Goldberg pioneered the widespread use of GA by enabling it to transition from theory to practice [25]. GA searches among a large number of individuals. Therefore, there is a control mechanism. This control mechanism is made by the fitness function. GA is a search and optimization algorithm based on natural selection and other genetic rules [26]. It is based on the principle that the best individual that exists in natural life survives and the others disappear. The best individual is determined through the fitness function. In addition, solution diversity is provided through operators such as crossover and mutation. The problems that GA produces the most appropriate solution are problems that cannot be solved by classical methods. Since GA does not need a derivative function, it can be preferred since it starts the solution steps with the initial solution without dealing with the content of the problem.

The gene is the smallest unit in GA that carries information on its own. Chromosomes are formed by the combination of genes. Gene structure depends entirely on the programmer's definition. Genes must be defined in the correct structure to solve the problem. It can contain a hexadecimal number system as well as a decimal number.

Chromosomes are genetic structures formed by the combination of multiple genes. It contains information about the solution to the problem. All chromosomes are possible sets of solutions for the problem. In this respect, the content of chromosomes must be created very carefully and must be controlled in iterated solutions.

Populations are clusters of chromosomes. Although the number of chromosomes in the population is fixed, it is determined by the programmer specific to the problem. When the genetic operators are processed, the chromosomes in the population disappear, and the population number is fixed with the addition of the newly formed chromosomes.

Segmentation of medical images [27], reallocation of load balances of virtual machines between resources [28], has been used by GA, Higazy, and Alyami [29] to model another current problem, COVID-19 outbreak transmission. GA has also been used in optimization[30] and classification problems [31].

2.2. Epigenetic

The word "epi" is a prefix and corresponds to expressions such as "besides, in addition, extra". Epigenetics refers to the variations that occur in parallel without affecting the base sequences of Adenine, Thymine, Guanine, and Cytosine that form the genetic code structure [32]. This means that Epigenetics falls outside the classical concept of genetics [33]. Without a change in Deoxyribonucleic Acid (DNA) sequence, the occurrence of changes at the gene level is called Epigenetics [34]. While epigenetics does not cause changes in DNA structure, it causes significant changes in the functioning of genes throughout the life span [35]. Conrad Waddington stated that mechanisms other than DNA sequence caused this differentiation during living development. Recent studies have demonstrated that Epigenetics plays a role in the regulation of gene expression not only during development but also in adult life Siegmund et al., [36]; Kouzarides [37]; Metivier et al., [38].

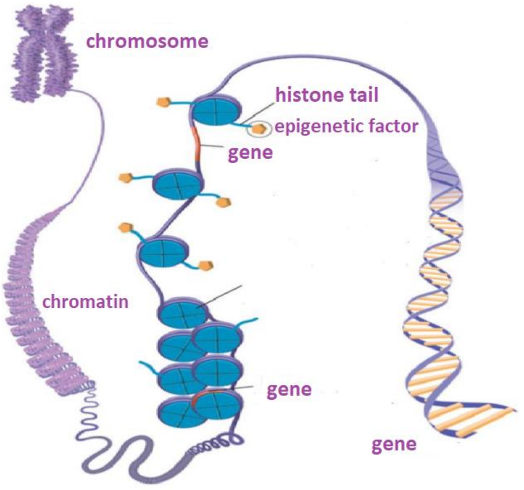

Figure 3. Basic structure of the epigenetic mechanism

Figure 3 shows the basic structure of the epigenetic mechanism biologically.

Epigenetic changes are stable and permanent [37]. However, Epigenetic changes are reversible [38]. The dynamic nature of epigenetics is due to changing conditions [39]. However, this feature makes it possible to control gene activity with the help of interventions such as changing environmental living conditions, drug use, and therapy administration. Thanks to this dynamic feature, Epigenetic changes form the basis of study when determining a new treatment strategy [39]. Epigenetics is inherited. This feature makes it possible to determine the effect of environmental conditions on gene expression, its benefit, and harm on that individual, and to be passed on to the next generations [40]. Epigenetics is a dynamic mechanism. This feature has enabled it to be arranged according to changing environmental conditions. It is possible to control gene expression with effects such as medication, nutrition, and treatment. In this case, the advantage or disadvantage caused by environmental conditions on gene expression can be carried over to the next generations Delcuve et al., [41]; Kaminsky et al., [42].

Mechanisms that allocate information in the structure of genes without changing the nucleotide sequence are called Epi. Epigenetic processes are natural and essential for living organisms. Epigenetic mechanisms can also create adverse effects for living organisms due to environmental conditions. Methylation, sumoylation, phosphorylation, ubiquitylation, and acetylation are among the types of epigenetic modification [43].

In another definition made for epigenetics, it was stated that it is a scientific field that allows the regulation of gene activities independent of gene sequence and the investigation of changes in gene expression [44].

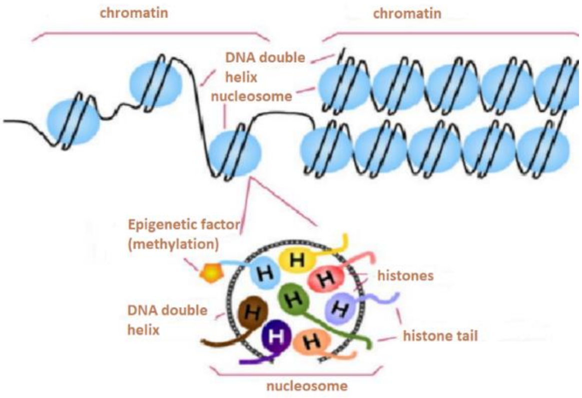

Figure 4. Epigenetic mechanisms

Figure 4 shows epigenetic factors and epigenetic mechanisms. Epigenetic tags form a second structural layer. Epigenetics contains DNA and all chemical tags in the structure of histone proteins to regulate gene activity (expression) in the gene structure. Thus, epigenetic gene activation and regulation of gene silencing can be realized [45].

2.3. Epigenetic Algorithm

The use of EGA in engineering applications has found a place in recent studies. Dipankar et al. by constructing the Genetic Algorithm developed a new genetic model called the Structured Genetic Algorithm (sGA). They did not mention the elements of EGA in their work but used gene activation that controls gene states of EGA. They used a model based on gene repression, not gene silencing. In this model, gene activity regulation was performed with a layered structure for genetic material and chromosomes. Thus, the crossing and mutation processes were made more efficient and convergence to the best solution was achieved. It has been proven by mathematical calculations that sGA provides better results theoretically than GA. It is determined that EGA will provide an effective solution in multi-stage optimization problems [46].

Tanev and Yuta developed a model with EGA in 2008. This model has allowed the development of an algorithm based on gene expression regulation using histone proteins and modifications. By detecting beneficial effects on GA performance with EGA, an effect on the evolutionary process has been achieved. In the study, EGA and GA results were compared for the predator-prey pursuit problem and it was found that EGA provided 2.1 times improvement [47].

Periyasamy et al. proposed EGA as an optimization strategy with the Epigenetic mechanism based on the intergenerational adaptation of the biological process. It has been determined that cellular processes are aimed at achieving optimization of biochemical molecules with an adaptive strategy in organisms [48].

Sousa and Costa have proposed an Epigenetics-based approach called EpiAl. There are two main entities in this approach: agents and the environment. Agents change phenotype levels with the help of environmental conditions. An agent acts as a regulator of gene expression according to stimuli from the environment. Apart from that, they argued that it can be determined whether the inheritance process will occur between generations with epigenetic signs. While epigenetically unchanged populations could not survive under changing living conditions, epigenetically modified populations adjusted themselves by adapting to the changing environmental conditions. As a problem application area, EPIAL has been applied by subjecting the agents to environments where the agents are changed periodically or non-periodically with three basic conditions such as temperature, light, and food [49].

Chikumbo et al. addressed the problem of land use management with the Epigenetics-based Evolutionary Algorithm. The land has been identified near Rotorua, New Zealand, and they have ensured sustainable land use [50].

Turner et al. proposed the Artificial Epigenetic Regulatory Network (AERN) by developing the artificial gene regulation (AGN) model. The artificial epigenetic regulation network initially starts by making use of the Genetic Algorithm. The network provides efficiency thanks to its ability to disable genes. Recovery is provided with the genes that are disabled. By combining epigenetic elements with chromatin modifications in the artificial epigenetic regulation network, the exchange of Epigenetic information has been provided by DNA methylation. The development of the network is provided by epigenetic control, and in this model, if subsets of genes are active, the probability of realizing a target increases. The purpose of this process is to represent the process governed by the rules of evolution and to follow a specific trajectory [51].

La Cava et al. used a Developmental Linear Genetic Programming model with an Epigenetic mechanism and presented a model to solve the symbolic regression problem. Epigenetic properties of genotypes representing equations are optimized with a model called an epigenetic hill climber. The epigenetic hill climber has a genotype consisting of a list of tasks and also a binary sequence of equivalent length is created for each individual. The concept of Epiline is used for this dual sequence. During the conversion from genotype to phenotype, not only Epiline but all active tasks are fulfilled [52].

Stolfi and Alba developed the Epigenetic Algorithm and used four epigenetic operators. The first operator is the Start operator, which creates cells. The second operator is the Nucleosome production operator. The third operator is the Nucleosome-based reproduction operator, where the Epigenetic rules are followed. The fourth operator is the epigenetic mechanisms operator. Epigenetic mechanisms are the operator by which DNA methylation and adaptation to environmental conditions are determined. Each individual in the population harbors cells that offer different solutions to the problem. Each chromosome is represented as a dual vector. The first vector represents the possible solution to the chromosome problem in the population; the second vector represents the mask to be used in crossing. The structure, which is the second vector and called the mask, performs the same task as the Epigenetic Factor List in the Epigenetic Algorithm. Stolfi's work focused on the effect of EGA on gene replication to form nucleosomes with DNA and histone proteins, and on the effect of epigenetic mechanisms on gene expression Rosso [53]; Stolfi and Alba, [54].

Ricalde introduced a new approach to Genetic Programming inspired by Epigenetics. In this approach, chromosome regions affected by environmental factors are activated and deactivated. A task-based application is carried out with DNA methylation in epigenetic mechanisms. These mechanisms only affect conditional nodes. Ricalde, on the other hand, aims an adaptable model by evaluating the diversity of the environment and adding the changes in the environment to the calculations. The mechanism enables the calculation of changes in the environment by performing epigenetic mutations. Ricalde proposed solutions for changing environmental conditions and reported Genetic Programming performance improvements. Thus, it has become that individuals can adapt to environmental conditions more easily. Ricalde developed this method to control the traffic signal [55].

Epigenetic algorithms have been applied in the field of optimization and planning of the Global System for Mobile Communications (GSM) mobile frequencies [56]. Epigenetics has been used in the Intrusion Detection System for study purposes study to assist in identifying crossing and mutation processes based on the randomness of the Genetic Algorithm [57]. It was emphasized that there are two types of attack detection systems, the first is to detect attacks made with known signatures, and the second is that abnormal behaviors are detected by heuristic approaches. Epigenetic Algorithm optimizes by hybridizing heuristic algorithms to get the best solution. Factors introduced in addition to the Genetic Algorithm have led to the emergence of new hybrid algorithms. As a result of the research, epigenetics that examines gene expression without changing the gene sequence has led to the discovery. Epimutation and Epicrossover have been added to the classical Genetic Algorithm to approach a better solution and help reduce the number of iterations. Epigenetics is a mechanism that controls the activation of chromosome structure or the regulation of inactivated genes. With the Epigenetic Algorithm, the solution to the multidimensional backpack problem (Knapsack Problem) has been developed. Ezzarii et al., in another study, developed an attack detection system for advanced threats and emphasized that an Epigenetic Algorithm-based attack classifier provides higher performance [58]

ALGORITHM 1: EPIGENETIC ALGORITHM[56]

```
Create Initial Population
Define Constraints
do
        Evaluate the chromosomes according to a Fitness function
        Set epigenetic factors to genes that do not allow criteria (1) (epigenetic
        factors list)
                Apply Selection (Roulet whelle technique)
        Send the chromosomes to the Mating pool
                Apply Crossover operator
                Apply Epicrossover operate according to epigenetic factor list
                Apply Mutation operator
                Apply Epimutation operator according to epigenetic factor list
                Create the Next population from the previous population
        while (!(end of Generation) or (stop to get better))
                Take the best chromosome to the solution
        end
end
```

The pseudo-code of the epigenetic Algorithm is shown with Algorithm 1.

2.3.1 Epicrossover Operator

Although the Epicrossover process is similar to the Crossing process within the Genetic Algorithm, it shows fundamental differences. Randomness is the main factor in the Crossing process required for the Genetic Algorithm. The two genes are carried out at the rate determined by the type of crossing. Which genes to cross for epicrossover can be managed to a certain extent. To be able to manage this, the Epigenetic Factor List must be determined. Thanks to the Epigenetic Factor List, it is known throughout the chromosomes which genes are problematic. Any two genes to be crossed are presented to the crossing rate with the Epigenetic Factor List, shortening the steps to achieve the optimum result. With the Epigenetic Factor List, it is determined which genes are against the restrictions in terms of fitness.

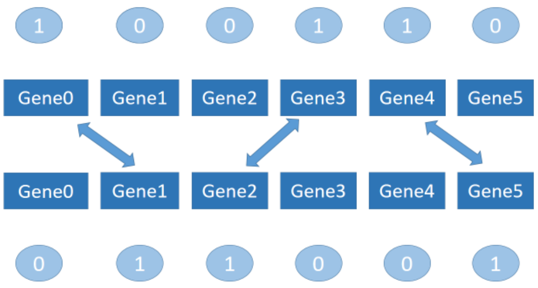

Figure 5. Epicrossover

Figure 5 shows the epicrossover operator and gene exchange is possible only between genes designated as 1.

2.3.2 Epimutation Operator

Epimutation operator; although it is similar to the Mutation process in the Genetic Algorithm, there are fundamental differences in the Epimutation process. The Mutation within the Genetic Algorithm is based on the principle that any two genes in the same chromosome are completely randomly selected and replaced at a predetermined rate. However, the Epimutation process ensures that this randomness is managed at a certain level.

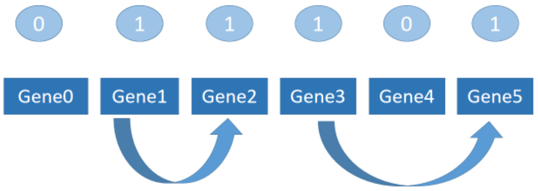

Figure 6. Epimutation

Figure 6 shows the Epimutation operator.

Epimutation, crossing in the Epigenetic Algorithm design, new individuals formed after mutation processes and individuals obtained after the Elitism process are kept in memory and transferred to new generations. Similarly, in the Epigenetic Algorithm design, an Epigenetic Factor List is created for each new generation by making epiheritance.

2.3.4 Epigenetic Factor List

Epigenetic Factor List, An Epigenetic factor list is created for each gene with or without a penalty in Epigenetic design. This Epigenetic factor list created determines whether each gene will be active or not. Each gene is identified by a 1 or a 0 to determine whether it is active or not. Epigenetic factors occur by creating a list for the entire population and the entire chromosome. This list will facilitate the selection of genes that will participate in the crossing and mutation processes in the classical Genetic Algorithm.

It is the new transition operator that applies to genes with a value of '1' for epicrossover and epimutation.

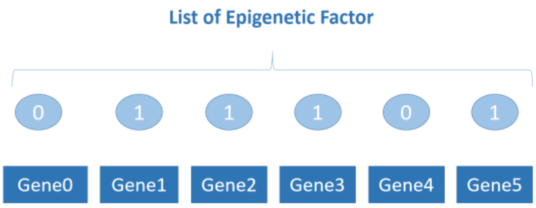

Figure 7. Epigenetic factor list

Figure 7 shows the generation of the Epigenetic factor list.

In this case, active genes and inactive genes are distinguished. After identifying the active genes and the inactive genes, the Epigenetic Factor List is created to apply the Epigenetic Algorithm. After the Epigenetic Factor List is prepared, Epicrossover and Epimutation processes are made ready to be carried out.

3. EXPERIMENTAL RESULTS

In this title, information on the comparative results of the conference scheduling process performed with the Genetic Algorithm and Epigenetic Algorithm is given. C# programming language was used to solve the problem with Genetic Algorithm and Epigenetic Algorithm. MS Access database software is used as a database. The developed software was tested on a computer with 8 GB Ram and 3.00 GHz 4-core Intel i5 processor running on Windows 10 operating system. The experiments determined for the Genetic Algorithm and Epigenetic Algorithm used in this study were run 10 times. In this study, data from 2 different multidisciplinary conferences are provided for the performance of the algorithms. The obtained data were recorded in the database and expressed with genes.

Table 1. Algorithm and Operator Information for 100 Paper Scheduling

Operator	Classical GA				EGA			
Crossover operator	90% Multi-point				85% Multi-point			
Epicrossover operator	-				35% Multi-point (epigenetic factor list)			
Mutation operator	0.1%				0.1% Two gene			
Epimutation operator	-				0.08% Two genes (epigenetic factor list)			
Epigenetic factor list	No				Yes			
Epigenetic inheritance	No				Yes			
Number of Population	10	10	10	10	10	10	10	10
Chromosome Length	300	360	450	540	300	360	450	540
Day	2	2	3	3	2	2	3	3
Session	6	6	6	6	6	6	6	6
Halls	5	6	5	6	5	6	5	6
Fitness Value	0.968144	0.960904	0.957574	0.951907	0.999033	0.999303	0.995117	0.994943
Number of Iterations	100000	100000	100000	100000	100000	100000	100000	100000

Table 1 shows the GA and EGA results for the conference scheduling problem with 100 papers.

Table 2. Algorithm and Operator Information for 242 Paper Scheduling

Operator	Classical GA				EGA			
Crossover operator	% 90 Multi-point				85% Multi-point			
Epicrossover operator	-				35% Multi-point (epigenetic factor list)			
Mutation operator	%0.1				%0.1 two genes			
Epimutation operator	-				%0.08 Two genes (epigenetic factor list)			
Epigenetic factor list	No				Yes			
Epigenetic inheritance	No				Yes			
Number of Population	10	10	10	10	10	10	10	10
Chromosome Length	300	360	450	540	300	360	450	540
Day	2	2	3	3	2	2	3	3
Session	6	6	6	6	6	6	6	6
Halls	5	6	5	6	5	6	5	6
Fitness Value	0.9881	0.9865	0.9824	0.9811	0.9986	0.9978	0.9941	0.9935
Number of Iterations	100000	100000	100000	100000	100000	100000	100000	100000

Table 2 shows the GA and EGA results for the conference scheduling problem with 242 papers.

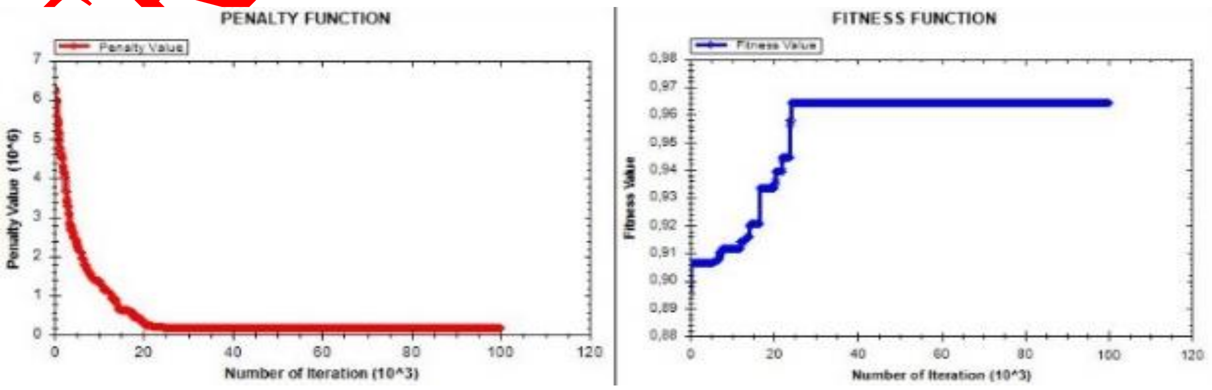

Figure 8. 100 Papers, 2 days 6 sessions 5 halls Genetic Algorithm

Figure 8 shows the Penalty function and Fitness Function for 100 papers, 2 days 6 sessions 5 halls with a Genetic Algorithm. The penalty function and fitness function graph in this scenario with 100 papers is shown. The penalty value started from 6105672. The penalty value has decreased to 174679.

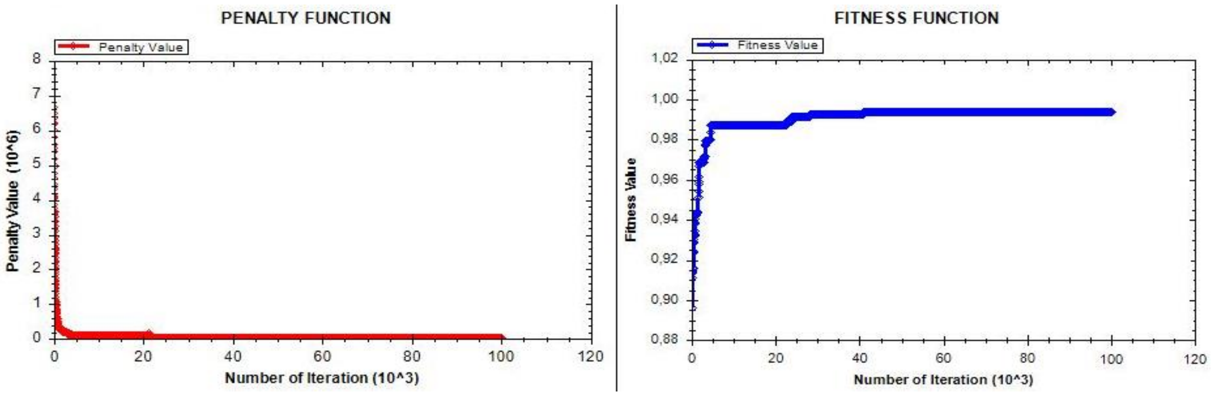

Figure 9. 100 Papers, 2 days 6 sessions 5 halls Epigenetic Algorithm

Figure 9 shows the Penalty function and Fitness Function for 100 papers, 2 days 6 sessions 5 halls.

The penalty function and fitness function graph are shown in this scenario with 100 papers. The penalty value initially started as 6274811. The penalty value has decreased to 12003. When the graphs of penalty values and fitness values shown in Figure 7 are examined, it is revealed that the Epigenetic Algorithm is more efficient than the Genetic Algorithm in terms of both penalty value and fitness value.

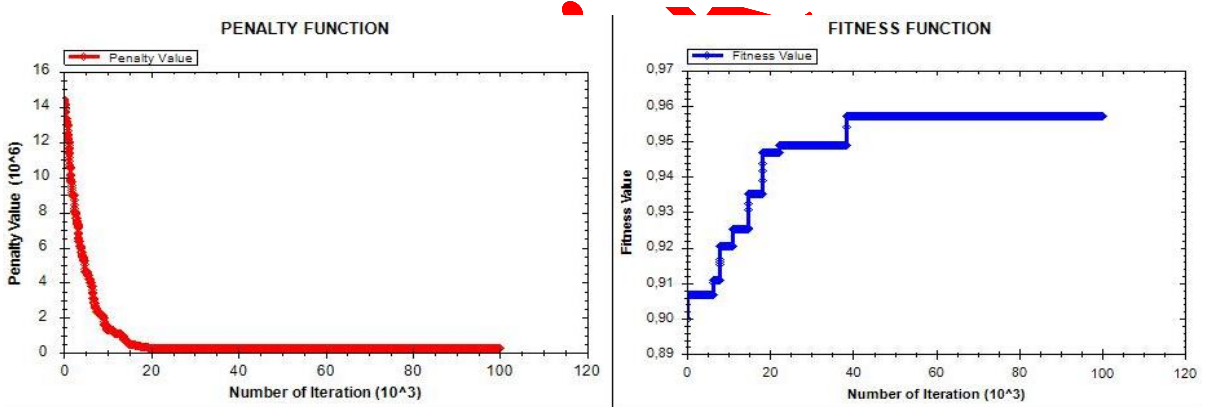

Figure 10. 100 Papers, 3 days 6 sessions 6 halls Genetic Algorithm

Figure 10 shows the Penalty function and the fitness function for 100 papers, 3 days 6 sessions 6 halls. The penalty function and fitness function graph in this scenario with 100 papers is shown. The penalty value has decreased to 740650. The fitness value increased to 0.9519.

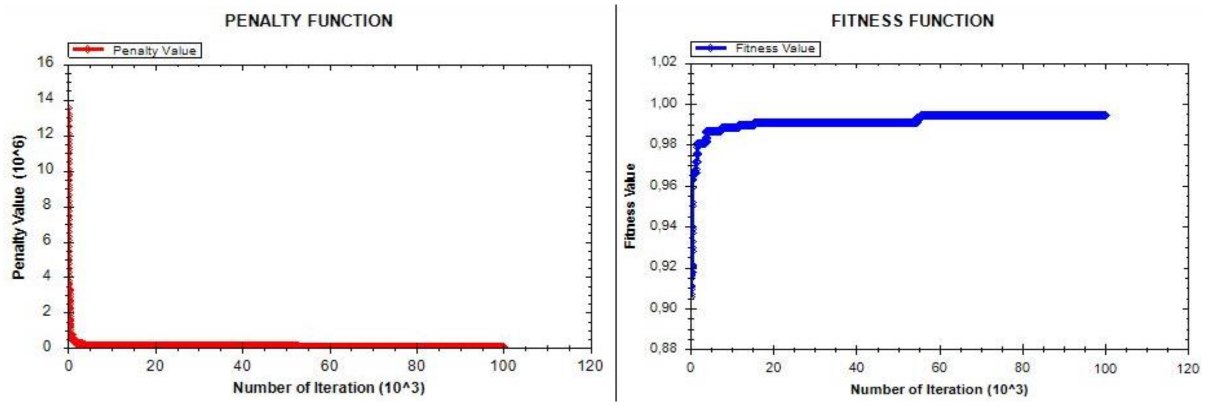

Figure 11. 100 Papers, 3 days 6 sessions 6 halls Epigenetic Algorithm

Figure 11 shows the Penalty function and the fitness function for 100 papers, 3 days 6 sessions 6 halls. The fitness value increased to 0.994943.

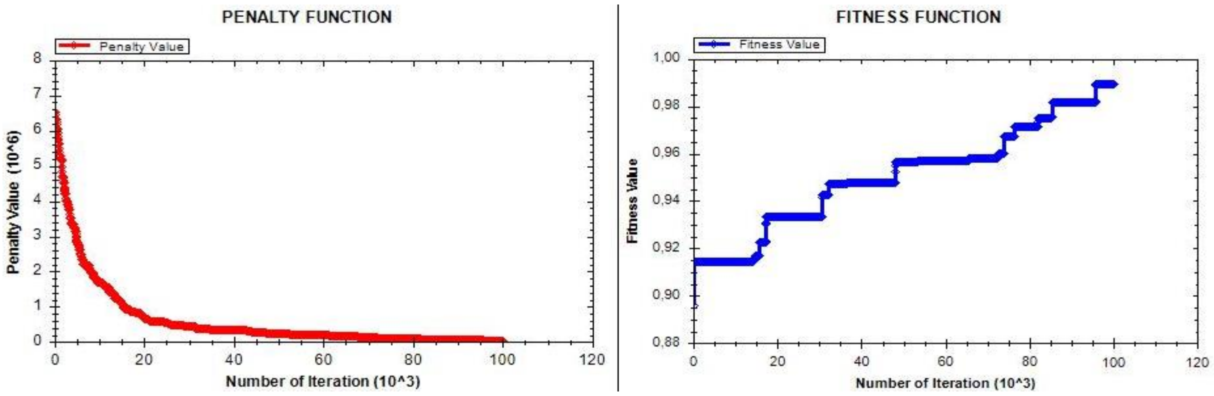

Figure 12. 242 Papers, 2 days 6 sessions 5 halls Genetic Algorithm

Figure 12 shows the Penalty function and the fitness function for 242 papers, 2 days 6 sessions 5 halls. The fitness value increased to 0.9881.

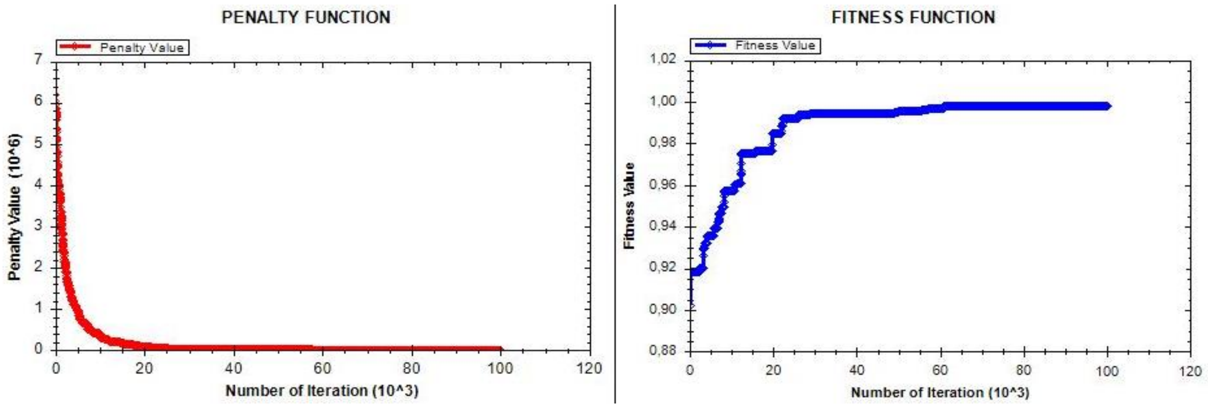

Figure 13. 242 Papers, 2 days 6 sessions 5 halls Epigenetic Algorithm

Figure 13 shows the Penalty function and Fitness Function for 242 papers, 2 days 6 sessions 5 halls. The fitness value increased to 0.9986.

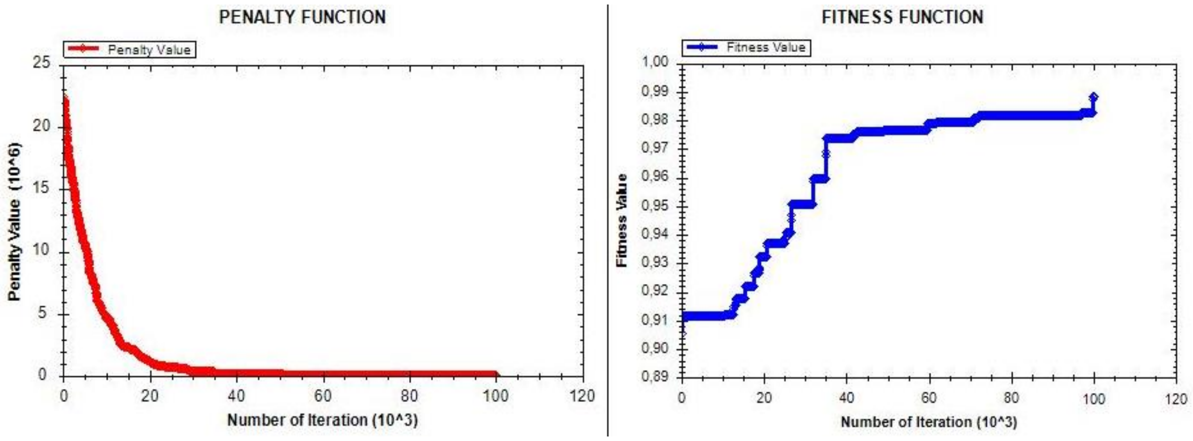

Figure 14. 242 Papers, 3 days 6 sessions 6 halls Genetic Algorithm

Figure 14 shows the Penalty function and Fitness Function for 242 papers, 3 days 6 sessions 6 halls. The fitness value increased to 0.9811.

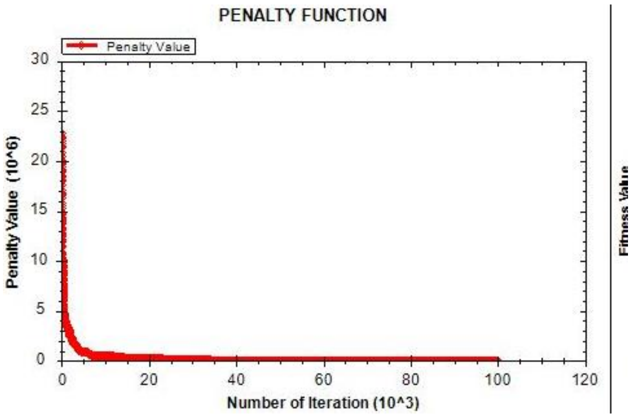

Figure 15. 242 Papers, 3 days 6 sessions 6 halls Epigenetic Algorithm

Figure 15 shows the Penalty function and Fitness Function for 242 papers, 3 days 6 sessions 6 halls.

The penalty function and fitness function graph in this scenario with 242 papers is shown. The penalty value has decreased to 91527. The fitness value increased to 0.9519. When the graphs of penalty values and fitness values shown in Figure 14 are examined, it is revealed that the Epigenetic Algorithm is more efficient than the Genetic Algorithm in terms of both penalty value and fitness value. This situation shows that 242 papers are bigger than the scheduling made with 3 days 6 sessions and 6 halls. This situation reveals that as the number of papers increases, scheduling becomes more difficult. In addition, scheduling 300 papers with 3 days and 6 sessions with 6 halls has been more difficult than scheduling 2 days, 6 sessions with 5 halls. The penalty value generated in the first iteration is higher in the case of 3 days 6 sessions 6 halls. This situation shows that the solution space is getting bigger. Although 3 days 6 sessions 6 halls show a greater improvement in terms of the first iteration, the solution obtained at the end of the algorithm reveals that the result obtained with 2 days 6 sessions 5 halls is closer to the best solution. Scheduling 242 papers in 3 days 6 sessions with 6 halls is also more difficult than scheduling 242 papers with 2 days 6 sessions and 5 halls. Because the solution space of the scheduling made with 3 days 6 sessions and 6 halls is larger. In the larger solution space, convergence to the best solution becomes more difficult. This situation is reflected in the smallest penalty value obtained.

4. CONCLUSION

Within the scope of this study, the conference scheduling problem was solved with a Genetic Algorithm and an Epigenetic Algorithm based on the real data of the multidisciplinary conference. In the conference scheduling problem, the decision variables regarding the number of days, sessions, and halls affect the scheduling performance. In order to schedule a conference in the best way, it is necessary to prepare the balance between the number of days, the number of sessions and the number of halls, and the number of conference papers. This process is an important factor in a dynamic scheduling solution. This situation will give a positive reaction to the dynamic change of the needs of the conference in today's conditions. In this problem solved with the Epigenetic Algorithm, apart from classical crossover and classical mutation operators, epicrossover and epimutation operators were applied according to the Epigenetic Factor List for the application. In this way, better results were obtained with the Epigenetic Algorithm. The epigenetic structure, which was developed with inspiration from the field of biology and biotechnology, has been used in software and especially in optimization problems. By ensuring the integration of the Epigenetic structure with the Genetic Algorithm, it ensures that the understanding of the randomness of the Genetic Algorithm is partially managed. In this way, better solutions are obtained by enabling gene exchange in a more controlled manner. One of the experimental results obtained within the scope of the study is the free time situation. As the number and capacity of papers in a conference increases, the number of free time will also increase. In this case, while the number of papers was fixed, it was determined that the initial value of the penalty was greater in the experiments performed by increasing the capacity. Capacity expansion can enable scheduling on a larger scale. However, the initial penalty value is higher. This situation changes the priority order of the applied algorithms for optimization. When the number of papers is fixed and the capacity increases, both the Genetic Algorithm and the Epigenetic Algorithm will start to postpone the empty sessions until the last session on the last day of the conference since the initial penalty value starts with a higher value. Then, it will start to make the primary sub-fields, secondary sub-fields, and tertiary sub-fields of the studies in the same sessions in the same way whether there is work by the same author in concurrent sessions. In addition, in cases where the number of capacity increases, when the initial penalty value is compared with the last penalty reached, the most improvement is seen in cases where the capacity is high. However, this improvement is in the context of optimization and does not provide an advantage for the end-user. The ability of the software to provide the best service to the end-user will not have the improvement values achieved by the algorithms, and when the program is stopped, it will be questioned whether the solution obtained is available in the industry. It has been observed that determining the number of days, sessions, and halls, which are the parameters of the capacity variable, constitutes the important decision variable of the conference scheduling problem. In this respect, it was observed that the best schedule situations were obtained with this study when the number of papers and capacity were the same. The Genetic Algorithm and Epigenetic Algorithm begin problem-solving with an initial population. This starting population is randomly generated. In the experimental results and the graphs obtained, it was observed that the penalty value decreased in all scenarios in the iterations immediately after the initial population. This is true for both the Genetic Algorithm and Epigenetic Algorithm. This proves that the starting population was randomly generated. In addition, this situation reveals that it is not acceptable to solve combinatorial problems such as scheduling problems in completely random steps. The complexity levels discussed and defined in the program developed within the scope of this study were prepared by considering today's conference needs. Algorithms such as Genetic Algorithm, and Epigenetic Algorithm are among meta-heuristic algorithms. In this study, articles belonging to 2 different conferences were obtained and recorded in the database to obtain experimental results. In the studies in the literature, other methods such as simulated annealing, integer programming, and linear programming, which are heuristic and meta-heuristic algorithms for the conference scheduling problem, have been proposed for the solution. It has been revealed that the Epigenetic Algorithm structure, inspired by the medical field, saves the classical Genetic Algorithm structure from the understanding of full randomness in optimization problems in the software field. Thus, the Epigenetic Algorithm, which provides partial control under certain conditions, emerges. In the case of controlled gene exchanges, the Epigenetic Algorithm gives better results in a shorter time than the Genetic Algorithm. In this way, a better solution has been obtained. Other researchers may be able to compare the Epigenetic Algorithm with other metaheuristic algorithms for other problems in future studies. In addition, it has been paved the way for other researchers to study whether there is a successful solution algorithm for other problems with the Epigenetic Algorithm.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in their studies do not require ethical committee approval and legal-specific permission.

AUTHORS' CONTRIBUTIONS

Ercan ATAGÜN: Performed the experiments and analyse the results. Developed the program. Wrote the manuscript.

Serdar BİROĞUL: Performed the experiments and analyse the results. Designed the algorithm.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

[1] Zilberstein, S., Koehler, J., and Koenig, S. , "The fourteenth international conference on automated planning and scheduling (ICAPS-04)", ***AI Magazine***, 25(4), 101-101, (2004).

[2] Aktay, S., "How to organize a symposium: tracking digital footprints", **Electronic Turkish Studies**, 12(23), (2017).

[3] Andlauer, O., Obradors-Tarragó, C., Holt, C., and Moussaoui, D. , "How to organize and manage scientific meetings", **Psychiatry in Practice: Education, Experience, and Expertise**, 10(50), 97, (2016).

[4] Nicholls, M. G. , "A small-to-medium-sized conference scheduling heuristic incorporating presenter and limited attendee preferences", **Journal of the Operational Research Society**, 58(3), 301-308, (2007).

[5] Potthoff, R. F., and Brams, S. J. , "Scheduling of panels by integer programming: results for the 2005 and 2006 new orleans meetings", **Public Choice**, 131(3), 465-468, (2007).

[6] Zulkipli, F., Ibrahim, H., and Benjamin, A. M., "Optimization capacity planning problem on conference scheduling", **In 2013 IEEE Business Engineering and Industrial Applications Colloquium (BEIAC),** (pp. 911-915). (2013).

[7] Eglese, R. W., and Rand, G. K. , "Conference seminar timetabling", ***Journal of the Operational Research Society***, 38(7), 591-598, (1987).

[8] Ibrahim, H., Ramli, R., and Hassan, M. H., "Combinatorial design for a conference: constructing a balanced three-parallel session schedule", ***Journal of Discrete Mathematical Sciences and Cryptography***, 11(3), 305-317, (2008).

[9] Sampson, S. E., and Weiss, E. N. , "Designing conferences to improve resource utilization and participant satisfaction", ***Journal of the Operational Research Society***, 47(2), 297-314, (1996).

[10] Sampson, S. E. , "Practical implications of preference-based conference scheduling", ***Production and Operations Management***, 13(3), 205-215, (2004).

[11] Thompson, G. M. , "Improving conferences through session scheduling", ***Cornell Hotel and Restaurant Administration Quarterly***, 43(3), 71-76, (2002).

[12] Bhardwaj, A., Kim, J., Dow, S., Karger, D., Madden, S., Miller, R., and Zhang, H. , "Attendee-sourcing: Exploring the design space of community-informed conference scheduling", ***In Second AAAI conference on human computation and crowdsourcing***, Pittsburgh, USA, pp. 2-10, (2014).

[13] Tanaka, M., Mori, Y., and Bargiela, A. (2002) "Granulation of keywords into sessions for timetabling conferences", ***in Proceedings of soft computing and intelligent systems (SCIS)***, Tsukuba, Japan, pp.1-5

[14] Mori, Y., Tanaka, M. , "A hybrid genetic algorithm for timetabling of conference programs", ***in: Proceedings of the 4th International Conference on the Practice and Theory of Automated Timetabling (PATAT 2002)***, Gent, Belgium, pp.421–440, (2002).

[15] Edis, E. & Sancar Edis, R. , "An integer programming model for the conference timetabling problem', ***Celal Bayar University Journal of Science***, 9(2), 55-62, (2013).

[16] Stidsen, T., Pisinger, D., and Vigo, D. , "Scheduling EURO-k conferences", ***European Journal of Operational Research***, 270(3), 1138-1147, (2018).

[17] Correia, R., Subramanian, A., Bulhões, T., and Penna, P. H. V. , "Scheduling the Brazilian or conference", ***Journal of the Operational Research Society***, 1-12, (2021).

[18] Bulhões, T., Correia, R., and Subramanian, A. , “Conference scheduling: A clustering-based approach”, ***European Journal of Operational Research***, 297(1), 15-26, (2022).

[19] Doshi, V., Tuteja, S., Bharadwaj, K., Tantillo, D., Marrinan, T., Patton, J., and Marai, G. E. , “StickySchedule: an interactive multi-user application for conference scheduling on large-scale shared displays”, ***In Proceedings of the 6th ACM International Symposium on Pervasive Displays***,(pp. 1-7), (2017).

[20] Castaño, F., Velasco, N., and Carvajal, J. , “Content-based conference scheduling optimization”, ***IEEE Latin America Transactions***, 17(04), 597-606, (2019).

[21] Eltayeb, I. S., and Ahmed, A. S. , “A comparison of selection hyper-heuristic approaches on the conference scheduling optimization problem”, ***In 2020 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE),*** (pp. 1-6), IEEE, (2020).

[22] Howells, J., Ramlogan, R., and Cheng, S. L. , ”Universities in an open innovation system: a UK perspective”, ***International Journal of Entrepreneurial Behavior & Research***, 18(4), 440–456, (2012).

[23] Dimitrios, N. K., Sakas, D. P., and Vlachos, D. S. , “Modeling the scientific dimension of academic conferences”, ***Procedia-social and behavioral sciences***, 147, 576-585, (2014).

[24] Holland, J.H. , “Adaptation in natural and artificial systems”, ***The University of Michigan Press***, Ann Arbor, USA, (1975).

[25] Goldberg, D. E. , “Genetic algorithms in search, optimization, and machine learning”, **Addion wesley**, Boston, USA, (1989).

[26] Davis, L. , “Handbook of genetic algorithms”, ***Van Nostrand Reinhold***, Michigan, USA, (1991).

[27] Hilali-Jaghdam, I., Ishak, A. B., Abdel-Khalek, S., and Jamal, A. , “Quantum and classical genetic algorithms for multilevel segmentation of medical images: A comparative study”, ***Computer Communications***, 162, 83-93, (2020).

[28] Zhang, B., Wang, X., and Wang, H. , “Virtual machine placement strategy using cluster-based genetic algorithm”, ***Neurocomputing***, 428, 310-316, (2021).

[29] Higazy, M., and Alyami, M. A. , “New caputo-fabrizio fractional order SEIASqEqHR model for COVID-19 epidemic transmission with genetic algorithm based control strategy”, ***Alexandria Engineering Journal***, 59(6), 4719-4736, (2020).

[30] Yüksek, G., Mete, A. N., and Alkaya, A. , “PID parametrelerinin lqr ve ga tabanlı optimizasyonu: sıvı seviye kontrol uygulaması”, ***Politeknik Dergisi***, 23(4), 1111-1119, (2020).

[31] Karasu, S., and Saraç, Z. “Güç kalitesi bozulmalarının hilbert-huang dönüşümü, genetik algoritma ve yapay zeka/makine öğrenmesi yöntemleri ile sınıflandırılması”, ***Politeknik Dergisi***, 23(4), 1219-1229, (2020).

[32] Hartl, D. L., and Jones, E. W. , “Genetics: analysis of genes and genomes”, **Jones & Bartlett Learning**, Canada, (2009).

[33] Jaenisch, R., and Bird, A. , “Epigenetic regulation of gene expression: how the genome integrates intrinsic and environmental signals”, ***Nature genetics***, 33(3), 245-254, (2003).

[34] Madlung, A., and Comai, L. , “The effect of stress on genome regulation and structure”, **Annals of Botany**, 94(4), 481-495, (2004).

[35] Jirtle, R. L. , “Epigenome: the program for human health and disease”, ***Epigenomics***, 1(1), 13-16, (2009).

[36] Siegmund, K. D., Connor, C. M., Campan, M., Long, T. I., Weisenberger, D. J., Biniszkiewicz, D., ... and Akbarian, S. , “DNA methylation in the human cerebral cortex is dynamically regulated throughout the life span and involves differentiated neurons”, ***PloS one***, 2(9), e895, (2007).

[37] Kouzarides, T., “Chromatin modifications and their function”. ***Cell***, 128(4), 693-705, (2007).

[38] Métivier, R., Gallais, R., Tiffoche, C., Le Péron, C., Jurkowska, R. Z., Carmouche, R. P., ... and Salbert, G. , “Cyclical DNA methylation of a transcriptionally active promoter”, ***Nature***, 452(7183), 45-50, (2008).

[39] Koçak, E. E., and Ertuğrul, A. , ”Psikiyatrik bozukluklar ve epigenetic”, ***Türk Psikiyatri Dergisi***, 23(2), 130-140, (2012).

[40] Richards, E. J. , “Inherited epigenetic variation—revisiting soft inheritance”, ***Nature Reviews Genetics***, 7(5), 395-401, (2006).

[41] Delcuve, G. P., Rastegar, M., and Davie, J. R. , “Epigenetic control”, ***Journal of cellular physiology***, 219(2), 243-250, (2009).

[42] Kaminsky, Z. A., Tang, T., Wang, S. C., Ptak, C., Oh, G. H., Wong, A. H., ... and Petronis, A. , “DNA methylation profiles in monozygotic and dizygotic twins”, ***Nature genetics***, 41(2), 240-245, (2009).

[43] Camacho L.A., Universidad Nacional de Colombia Engineering School Computer Systems Engineering (2020), Modeling Epigenetic Evolutionary Algorithms: An approach based on the Epigenetic Regulation process, [online], https://repositorio.unal.edu.co/handle/unal/78751

[44] National Institute of Environmental Health Sciences NIEHS, (2017) Roadmap epigenomics program, [online] https://www.niehs.nih.gov/research/supported/health/envepi/roadmap/index.cfm

[45] Genetic Home Reference GHR, (2018) Help me understand genetics, [online] https://ghr.nlm.nih.gov/primer

[46] Dasgupta, D., and McGregor, D. R. (1993). sGA: A structured genetic algorithm. Glasgow: Department of Computer Science, University of Strathclyde

[47] Tanev, I., and Yuta, K. , “Epigenetic programming: Genetic programming incorporating epigenetic learning through modification of histones”, ***Information Sciences***, 178(23), 4469-4481, (2008).

[48] Periyasamy, S., Gray, A., and Kille, P. (2008) ‘The epigenetic algorithm’, ***in 2008 IEEE Congress on Evolutionary Computation (IEEE World Congress on Computational Intelligence***, Hong Kong, China, pp.3228-3236

[49] Sousa J. and Costa E. (2010) ‘EPIAL - An Epigenetic Approach for an Artificial Life Model’, ***in Proceedings of the 2nd International Conference on Agents and Artificial Intelligence*** - Volume 1: ICAART, ISBN 978-989-674-021-4, pp.90-97. DOI: 10.5220/0002732500900097

[50] Chikumbo, O., Goodman, E., and Deb, K. (2012) ‘Approximating a multi-dimensional Pareto front for a land-use management problem: A modified MOEA with an epigenetic silencing metaphor’, ***in 2012 IEEE congress on evolutionary computation***, Brisbane, QLD, Australia, pp. 1-9

[51] Turner, A. P., Lones, M. A., Fuente, L. A., Stepney, S., Caves, L. S., and Tyrrell, A. M. , "The incorporation of epigenetics in artificial gene regulatory networks", ***BioSystems***, 112(2), 56-62, (2013).

[52] La Cava, W., Spector, L., Danai, K., and Lackner, M. 2014. Evolving differential equations with developmental linear genetic programming and epigenetic hill climbing. ***In Proceedings of the Companion Publication of the 2014 Annual Conference on Genetic and Evolutionary Computation***, New York, USA, pp. 141-142

[53] Rosso, D. H. S. (2018). Bio-inspired computing and smart mobility, Doctoral dissertation, Universidad de Málaga,[online] https://dialnet.unirioja.es/servlet/tesis?codigo=256401

[54] Stolfi, D. H., & Alba, E. , "Epigenetic algorithms: A New way of building GAs based on epigenetics", ***Information Sciences***, 424, 250-272, (2018).

[55] Ricalde, E. (2019) A Genetic programming system with an epigenetic mechanism for traffic signal control [online], https://arxiv.org/abs/1903.03854

[56] Birogul, S. , "EpiGenetic algorithm for optimization: Application to mobile network frequency planning", ***Arabian Journal for Science and Engineering***, 41(3), 883-896, (2016).

[57] Ezzarii, M., Elghazi, H., El Ghazi, H., and Sadiki, T. (2016) Epigenetic algorithm for performing intrusion detection system. ***In 2016 International Conference on Advanced Communication Systems and Information Security (ACOSIS)***, pp. 1-6

[58] Ezzarii, M., El Ghazi, H., El Ghazi, H., and El Bouanani, F. , "Epigenetic algorithm-based detection technique for network attacks", ***IEEE Access***, 8, 199482-199491, (2020).