Optimization of the allocation of academic schedules through artificial intelligence techniques

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Abstract. The programming or assignment of academic schedules in educational institutions has become an important global problem, this is due to the fact that it implies great efforts in time and resources for the staff a burden of this task due to the amount of restrictions and conditions that exist properly involved from the institution. Based on this problem and considering that common algorithms do not offer an optimal solution in this situation, it is necessary to resort to artificial intelligence techniques because they offer methods and algorithms that reduce the time and resources needed to generate an optimal program. This document details different artificial intelligence techniques used for the allocation of schedules, in order to find the technique that best suits the needs of the institution under study Universidad Francisco de Paula Santander, Ocaña located in Colombia, and which will be implemented more forward as a possible solution for the allocation of academic schedules in the institution.

1. Introduction

Educational timetabling is “the allocation, subject to restrictions, of a group of resources to objects located in time and space, so that a set of desired objectives are met” according to [1]. Several studies have been done about the subject in Nuevo León [2], genetic algorithms were applied to determine the most appropriate academic load for each professor of the institution, considering the various factors involved, at the Universidad de los Andes a Heuristic model based on integer binary programming for the problem of assigning classrooms, which considers teachers' preferences for a specific schedule and classrooms [3]. Similarly, the Universidad del País Vasco [4] designed a general model of an algorithm that generates near-optimal solutions in reasonable times and at the Universidad de la República in Uruguay [5], metaheuristics were applied in the development of these types of problems. The engine built includes the combination of the most important metaheuristics such as genetic algorithms, taboo search and within optimization by ant colony.

The Universidad del Caribe [6], presented a new way of representing individuals (chromosome) in the application of genetic algorithms in the problem of scheduling times and was developed by the degree program of telematic engineering. The Universidad del Norte [7], proposed to deal with the problem of organizing and distributing class schedules using the availability of teachers as one of the fundamental pillars. The Universidad Tecnológica de Pereira [8], presented a computer system that supported the process of assigning academic load using programming with restrictions, which allowed to delimit the time allocation related to the limits of each teacher, in other words, its classification (professors or hired by contract).
At the Universidad Nacional Mayor de San Marcos in Lima, Perú [9], it is proposed that the effectiveness of the solutions generated by an algorithm depends largely on an excellent definition of its evaluation function and the coding made of the problem. Another work at the Universidad ICESI [10], formulated a knowledge management model for schedule programming that consists of eight stages in order to convert tacit knowledge associated with schedule programming into explicit knowledge. An article presented at the Politécnico di Milano [11], shows an investigation that sought to measure the possibilities offered by genetic algorithms in the solution of time allocation problems and the comparison with other metaheuristics; the conclusion they reached was that the genetic algorithms produced better solutions than the simulated annealing algorithm, but they were not as good as the results of the taboo search algorithm, however the genetic algorithms showed to have an advantage over the other algorithms because they allowed flexibility to adapt them and solve other problems of assigning schedules. Likewise, in the Institución de Educación Superior INACAP where the project for the generation of academic schedules was developed using genetic algorithms [12], the organization and representation of the input data through tables in a relational database was proposed, it allows to perform the combination of the data to generate the individual's chromosomes.

These works have in common the genetic algorithms, which are adaptive methods that can be used to solve search and optimization problems, it is based on the selection mechanisms that nature uses where the strongest or most adapted individuals of a population survive, being this an artificial intelligence technique that belongs to the branch of evolutionary computing. Currently, the allocation of schedules has become an important problem for different institutions, companies and organizations worldwide. The optimization of schedules is considered a problem of nondeterministic polynomial complete (NP-complete) type due to the large number of variables and present restrictions [13], and many of the algorithms or techniques used to solve this problem did not end up being efficient or, in other cases, effective because they do not comply with the restrictions, therefore it is necessary to look for new techniques that allow the optimization of time and resources in the allocation of schedules, according to this in recent years various techniques with artificial intelligence have been used to generate an optimal and effective solution to this problem.

In the Facultad de Ingeniería of the Universidad Francisco de Paula Santander Seccional Ocaña located in Colombia, the realization of the time allocation through a study already done, presented weaknesses in terms of time availability by the teachers, classroom inventory according to the capacities and resources that they offer. For this reason, a genetic algorithm was proposed as a solution for optimizing schedules [14]. This article aims this problem by investigating on the technique for its solution.

2. Methodology

For higher education institutions the allocation of schedules is one of the problems that must be solved, due to the number of classes and restrictions that it has [15], these may also vary depending on the institution where the process is being done and in most cases this process is done manually; Therefore, some solutions serve only the particular case, presenting itself as a consequence that traditional solutions are ineffective and inefficient because they are not able to adapt to the changes that occur. This problem was introduced for the second international schedule competition (ITC) where it is considered a standard and contains characteristics common to the variants of this problem [15]. To address this research, a documentary analysis has been made, which makes it possible to find references associated with the topic, using a descriptive approach to achieve a description of the most recommended artificial intelligence techniques for the allocation of schedules.

3. Developing

Next, an introductory section of artificial intelligence is presented and the revision of artificial intelligence techniques applicable to the field of study of time allocation is focused, focusing on genetic algorithms, clustering, multi-agent systems, among others.
3.1 Artificial intelligence

The artificial intelligence refers to technologies that are based on consciousness and cognition where systems are sought to obtain machine learning through experiences, although it is similar to human learning, this differs because machine learning can be fully represented by mathematical algorithms [16].

The use of artificial intelligence (AI) has grown exponentially in recent years, reaching areas such as medicine, where research is currently being conducted for use in computer-assisted detection systems in mammography and predictive systems in cardiology [18-19]. It can also be found in another field, such as image processing, where it is sought to optimize this process through AI algorithms [19]. These are some of the examples of the areas where AI is implemented, although it should be borne in mind that AI is involved in a large number of areas around the world where techniques are constantly being sought to help improve or optimize processes or support decision making. For the optimization of academic schedules, in [20] various artificial intelligence optimization algorithms are used to generate new parameters, which will then be adjusted and used as new instances of the problem to generate better solutions regarding optimization. The results obtained in [20] were promising since selecting a combination of 5% algorithms and parameters results were obtained that were above 10% of the generated solutions, if the complete execution of parameters and algorithms is performed.

3.2. Artificial intelligence techniques for the allocation of schedules

For the allocation of academic schedules, several algorithms with artificial intelligence have been generated, most of these take into account the optimization of two important factors such as the time and resources needed to perform these processes.

3.2.1. Multiagent systems. Multiagent systems are systems in which several agents interact and pursue a set of objectives or tasks to achieve a common goal, they also have many practical applications such as training control, health monitoring machines, consensus, etc. [21].

These systems have been proposed as a method of solution for the allocation of schedules by [22] where the solution is based on a multi-agent system design through negotiations with the Java agent development (JADE) framework, for this proposal. Initially, three types of agents are considered, which are coordinator, groups and teachers, the coordinators are responsible for creating and managing the agents of groups and teachers, the group agents are responsible for resolving conflicts between groups of teachers, and the latter are responsible for providing the information required by the proposed system, the process of operation of 3 stages, In the first stage a coordinating agent is created who will be in charge of managing the other 2 types of agents (groups, teachers), then this agent proposes an initial solution taking into account the restrictions of the institution and part of the ideal calendars provided by the master agents, in the second stage when all teacher agents are ready, the coordinating agent creates the group agents who obtain the restrictions, activities and programming requests from each master agent, a master agent can initiate a request to a group agent and vice versa, in the third and final stage the group agents check that there is no conflict in the allocation of schedules, in case of a crossover or a problem, group agents launch a new solution where all the agents of teachers involved are present until there are no problems or as many restrictions as possible are respected.

For the experimentation of this proposal, 4 countries were used as a case study with different characteristics each, which can be seen in Table 1, then based on the results obtained, the following percentages of effectiveness related to conflict resolution were determined, for Belize, 93.41%, Brazil 73.92%, Spain 100% and UK 100% were obtained [22].

3.2.2. Clustering. The unsupervised classification is commonly known as clustering, the main objective of a data grouping is to look for the real data of a set of instances, points, objects, the grouping can also be explained as a statistical method used to determine if each one of the patterns can be divided into several groups by making a certain number of comparisons of different characteristics [23].
Clustering has been used to generate solutions to the problem of allocation of schedules, [24] expose a solution where these algorithms are used as a complement to try to meet the maximum number of soft restrictions in schedules at the end of a university, the restrictions that were taken into account for this problem can be seen in Table 2. Finally, the execution of this proposal was carried out where the obtained results fulfilled the priority condition that was to treat the maximum number of soft constraints, in addition [24] concluded that the Fuzzy C-means grouping algorithms can be used to generate improved schedules in common professors between the departments and also that several types of events and characteristics of the resources of the problem could be considered in different methods of grouping types.

Table 1. Study cases.

|          | Bezile | Brazil | Spain | UK |
|----------|--------|--------|-------|----|
| Days     | 5      | 5      | 5     | 6  |
| Hours    | 6      | 5      | 7     | 5  |
| Groups   | 23     | 16     | 185   | 46 |
| Professors | 44   | 27     | 56    | 26 |
| Subjects | 24     | 12     | 78    | 25 |
| Activities | 703   | 400    | 817   | 163|

Table 2. Constraints considered.

| Soft constraints                                      | Hard constraints                                      |
|-------------------------------------------------------|-------------------------------------------------------|
| In laboratory room, it is feasible to conduct theory   | It is not possible to conduct laboratory session in a  |
| session.                                              | classroom with no laboratory facility.                |
| A specific session may be required to be provisioned   | One lecturer can take only two specific subjects       |
| in a specific time period.                            | related to specific branch and semester.              |
| Lecturers may choose to have all their sessions in a   | Different classes should not be allocated to one      |
| number of days and to conduct number of sessions free  | lecturer at same time.                               |
| days.                                                 |                                                       |
| Each lecturer has their minimum and maximum limit      | There should be sufficient university resources for    |
| of weekly working hours.                              | conducting the sessions as lecture halls and lecturers.|

3.2.3. Genetic algorithms. The genetic algorithms were presented in 1969 by [25], is a type of search algorithm based on the natural selection of Darwin and the genetic mechanism of evolution of organisms, its main components are coding mechanism, fitness function, operators genetic (selection, crossing and variation) and control parameters, when using a genetic algorithm the possible solutions become chromosomes or in other words individuals, several of these individuals form groups of initial solutions, after calculating the fitness function, individuals who meet the termination conditions can exit and the algorithm ends, otherwise these individuals will begin to perform genetic operators to form a new generation of population inheriting the characteristics of the old which allows it to evolve towards a better solution [26].

Sutar and Bichkar [27] present a system with genetic algorithms that aims to design a curriculum optimized for a week, considering Monday through Friday the working days and taking into account the following parameters and restrictions that can be seen in the Table 3 and in Table 4 respectively, this was worked with a set of data in real time at the Ambedkar technology university [27] and the algorithm proposal was implemented in Microsoft Visual Studio 2008 using the programming language VC++, once the algorithm was programmed they were passed to the tests where results were obtained positive showing that these types of algorithms help the solution and decrease the time required for these problems but it is not possible to optimize 100% available resources in any case.

3.2.4. Differential evolution. The differential evolution (DE) is one of the evolutionary algorithms proposed by [28-29]. The algorithm is a population-based search method, where the value of each variable is represented by a real number [29], This algorithm is widely used in solution methods for the
problem of assigning schedules due to the advantages it offers, such as its simple structure, ease of use, speed and robustness, and it has few parameters that a user must establish from experience.

| Table 3. Parameters considered. |
|---------------------------------|
| **Parameter**                   | **Quantity** |
| Number of branches              | 3            |
| Number of semesters in each branch | 8         |
| Number of students in each branch | 60          |
| Number of subjects in each semester | 5          |
| Number of lecturers in each branch | 20         |
| Number of class rooms for each branch | 5          |
| Class room capacity             | 60           |
| Time duration for 1 session      | 1 hour       |
| Working time                     | 9am - 6pm    |
| Lunch break                      | 1pm - 2pm    |

| Table 4. Constraints |
|----------------------|
| **Soft constraints** | **Hard constraints** |
| In laboratory room, it is feasible to conduct theory session. | It is not possible to conduct laboratory session in a classroom with no laboratory facility. |
| A specific session may be required to be provisioned in a specific time period. | One lecturer can take only two specific subjects related to specific branch and semester. |
| Lecturers may choose to have all their sessions in a number of days and to conduct number of session free days. | Different classes should not be allocated to one lecturer at same time. |
| Each lecturer has their minimum and maximum limit of weekly working hours. | There should be sufficient university resources for conducting the sessions as lecture halls and lecturers. |

3.2.5. Hyper-heuristics methods. The hyperheuristics [30] they are methods that generate or choose heuristics to solve a problem of optimization, these methods have the objective of generating a generalized solution of the problem, these can be based on the selection or generation and those of low level can be perturbative or constructive. In [30] the performance of different hyperheuristic evolutionary algorithms is examined, the which are widely used for time allocation problems due to the good results they offer, among which we find a hyperheuristic constructive selection (SCHH), a hyperheuristic constructive generation (GCHH), among others; additionally, the hybridization performance of constructive and perturbative hyperheuristics for the mastery of school hours is examined.

3.2.6. Particle swarm optimization. The particle swarm optimization was developed in 1995 by Dr. Eberhart and Dr. Kennedy, inspired by the social behavior of the flock of birds or fish [31]. In [32] This technique is used as an optimization method for the assignment of a university academic schedule. The technique is based on particles [32], each particle has a search speed in space to find a feasible solution and adjust its position according to its experience and that of the other particles, this speed is determined by anomalies, each particle when moving remembers its best position and its own information, in addition the particles share their information with the other neighboring particles and remember their best overall; Finally, each particle has its own value, which is updated if a better individual and global position is found.

4. Conclusions
Understanding timetabling as the satisfactory allocation of resources according to the desired objectives and being this subject studied by universities of both national and international nature, including the Universidad de los Andes, ICESI, Universidad del Norte, Tecnológica de Pereira, Universidad del Caribe, Universidad de la República de Uruguay, Universidad del País Vasco, Politecnico di Milano,
Universidad de Chile, is being seen as a common technique among them to solve this problem using genetic algorithms, which allow the designing of an optimized curriculum according to certain restrictions.

For the analysis of this problem, other techniques such as clustering or unsupervised classification were reviewed, being this a statistical method to make a certain number of comparisons of different characteristics giving solution to the problem of timetabling and multi-agent systems, which are systems where several agents interact, with particular tasks with a common purpose, these have been proposed as a solution for schedules through negotiations, considering three types of agents (coordinator, groups and teachers); The coordinators are responsible for creating and managing the group and teacher agents, the group agents are responsible for resolving conflicts between the groups of teachers, and the teacher agents are responsible for providing the information required by the proposed system.

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