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Mathematical Model for Optimization of University Courses timetabling applying the criteria of quality of instruction

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A B S T R A C T

Timetabling is one of the most difficult issues in the world; this is a combinatory optimization issue and it has been proven that it is a NP-Hard issue.
University Courses Timetabling is very important especially for the exams and courses. The manual solving of the Timetabling needs a broad domain of sources and time to create an applicable schedule with minimum interference in the curriculum and Professor's program is not easy. Different mathematical models and algorithms have been presented for this issue but each strategy considers different limitations according to its environment and factors. Timetabling is different for different university courses Timetabling. In this study a new multi objective mathematical model with new objective functions and new constrains has been presented for university courses timetabling. The present study tries to consider most restrictions for a training center. Finally the validity of the proposed model has been surveyed by a small numerical example and its solving by LINGO11 software shows that this model can satisfy all goals and limitations.

1. Introduction

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Timetabling can be the assigning of some people to some limited parts of time in order to fulfill a set of goals. An optimum solution for timetabling is difficult with only one innovative algorithm because of uncertainty to decide on the objective function. So a technique is needed to solve all required restrictions for finding a close solution to the optimization (Hashim et al 2013).

Designing a timetable is a very complicated and time – consuming task for the responsible staff, so to do it automatically can reduce the workload of the staff(Tsang et al 2004).

Due to the increase in courses, academic subjects and high volume of planned courses in a university, allocation of a right place without a software is very difficult considerate space limitations, type of user location, suitable time and Professor(T sang et al 2011). These issues usually have two kinds of limitation; severe and soft limitations. Sever limitations can be provided under all conditions. Severe limitations are conditions whose observation is needed for having correct and sufficient timetables like : (Hasanzadeh et al 2012).

Each professor is supposed to teach only one class in each period of time All considered classes have to be in timetable. All intended rooms should be in accordance with the teaching in terms of subject. Courses that have a common instructor can't be presented at the same time. Required courses supposed to be taken by a group of students must not be presented at the same time. Courses presented in one semester shouldn't be simultaneously, considering the courses chart.

Soft limitation is additional terms whose observation can help the efficiency of the timetable and they are not obligatory but their defect has to be decreased such as:

A professor is able to prefer special days and time for teaching (not obligatory) All classes had better formed in the morning or evening. The number of used classes should be at least. The capacity of the class should be considered classes intended for a professor don't change. The allocation which satisfies all soft limitations is called a justified timetable. The object of university courses timetable is to minimize the defect of the soft limitations in a justified timetable. The parts of this study continue as follows: In part 2 , the researches done in this aspect are surveyed. In part 3, the multi – objective optimization is analyzed. In part 4, university courses timetable is defined and examined. In part 5, the multi objective mathematical model is presented and described. In part 6, the numerical example is described and solved. In part 7, the result of the solved numerical example is analyzed. Part 8 includes the conclusion and the suggestion of the future activities.

2. Multi Objective Optimization

A multi objective optimization contain some objective function that have to be minimized or maximized. This optimization like the single objective optimization, has some positive limitations that should be satisfied by each answer (such as the responses of the optimization).

Here, the general form of the multi objective optimization is expressed:

Minimize/Maximize f(x), m=1,2,…,M;

Subject to

$g_i(x) >= 0$ j=1,2,…,J;

$h_k(x) = 0$ k=1,2,…,K;

$x_i(L) <= xi <= xi(U)$ i=1,2,…,n;

An X answer is a vector of N decision variables: X=(x1, x2, x3,…, xn). The set of the recent limitation is called variable limit that limits each decision variable to take the value between the lower limit xi(L) and the upper limit xi(U). This limit forms a variable space decision, D or in other words Decision space.

3. University Courses Timetabling

Weekly planning for university is a problem. So the courses have to be allocated to the time according to the soft and severe limitations. Severe limitations are supposed to be observed (some of them can be reversible under some conditions and with a high cost) and the object is to observe soft limitations (Hasanzadeh et al 1391). Weekly planning is a multi-dimensional problem in which students and professors are attributed to the courses, course group or classes. There are some limitations considering the user demand that have to be considered when the problem is solved (Karter and Laprute, 1998). A general definition of university courses timetabling might be in this way: it is a task including the allocation of some events (like courses and exams) to the limited set of periods of time or classes. With this definition, university course timetabling can be divided into 2 groups: course planning and exam planning that both have some common features according to the nature of the discussed factors in universities but the main difference is that in exam planning multiple events can be planned simultaneously in common periods and classes but it isn't in this way in In course planning in each period of time only one course of the group and only in one classes can be allocated (lowis,2006).

4. Literature Review

Asratian and Werra (2008) took a hypothetical model that extend the fundamental 'class-teacher model' of timetabling and is related to some conditions which often take place in the fundamental teaching programmers of universities and schools. They have shown that those problems are NP-hard so that they made an algorithm to create a timetabling which is related to requirement problem and showed that this algorithm can find feasible solution under a natural theory.

Daskalaki et al. (2004) proposed an integer programming formulation for university course timetabling. The formulation minimized the cost in the objective function. The presented model was solvable by integer programming solver software for large department. They tested this model with a case study and obtained good results.

Broek et al. (2009) proposed a comprehensive mathematical modeling and clarified all of the restrictions of a university. They used lexicographical optimization with four sub problems. Outputs revealed that this model is able to satisfy constraints.

Gunawan et al. (2012) considered a university course time tabling which integrates both teacher assignment and course scheduling. A first solution created by a mathematical programming method according to Lagrangian relaxation and the solution improved by a simulated annealing algorithm. This presented approach had been examined on instance and results revealed that the proposed approach is able to create good quality solutions.

Zanjirani Farahani & Haji yakhchali (2005) proposed an Integer mathematical model for Minimization of the interval between 2 continuous classes in one semester with using new limitations too and solved it by designing a software with visual basic.

Kaviani et al. (2013) present a mathematical model for university course timetabling. Their study tried to highlight university course time tabling, in which most requirements as well as constraints of an education center have been examined. Their model used a small numeral example was assessed by the software, called 'LINGO 9' whose results indicate that this model is capable of satisfying all limitations along with objectives.

Abdullah and Turabieh (2012) proposed a tabu-based mimetic algorithm that hybridizes a genetic algorithm with a tabu search algorithm. They proposed it as an improved algorithm. This algorithm was applied for a group of neighborhood structures during the search process with the goal of obtaining important developments in solution quality. The order of neighborhood structures had been regarded to find out its influences on the search space. Accidental, great and general orders of neighborhood structures had been analyzed in this study and it is found that the presented algorithm generates some of the greatest known conclusions when experimented on ITC2007 competition datasets.

Sabar et al. (2012) proposed a variant of the honey-bee mating optimization algorithm to solve educational timetabling problems. The performance of the proposed algorithm was tested over two benchmark problems: exam (Carter's un-capacitated datasets) and course (Socha datasets) timetabling problems. This approach had best results in comparison with other methods on some instances.

In Table 1, the features of some of researches mentioned above like Approach, limitations and Objective Functions describe complete.

Table 1 Research Background

Researchers	Approach	limitations	Objective Function
Asratian & verra 2008	Presentation of a theoretical model, an algorithm for making a timetable in accordance with limitations of the problem	No interface in professors schedule Specifying the number of the professor's presentations in each class. Planning for professors at the time of their attendance.	The reduction of the contradictions in limitations
Zanjirani Farahani & Haji yakhchali 2005	Zero – One Model	The complete presentation of all course unit in a week. Planning of courses at the time of professors attendance. No interference in professor's schedule. Required equipment for courses should be available. No interference in the venue of courses. Considering the capacity of the class in planning. No interference in student's schedule. Considering the time when classes are used. No change in the schedule of other faculties.	Minimization of the interval between 2 continuous classes in one semester

Researchers	Approach	limitations	Objective Function
Daskalaki et all. 2004	Planning of the number Zero – One	No interference in Professor's schedule. No interference in student's schedule. No interference in the venue of courses . The offering of all courses of a semester. The offering of the courses considering the number of the period required for each courses. The agreement between the number of all courses for each professor and his administrative tasks.	The minimization of the cost allocation for each course to each period of time. The minimization of the cost incurred in the allocation of additional sessions to the courses that require additional sessions.
Broek et all 2010	Complete mathematical formulation Problem solving by Optimization of Lexicography	Maximization of the students allocated to one session of the course Determining the number of the surplus students of a session Determining additional courses allocated to the student who are in the seventh to the tenth priority level if they are allocated to more than 1 course	Maximization the number of the courses allocated the emergency. Minimization the number of the students for lack of compulsory courses became some courses may not have enough students. Maximization of the volume of courses allocated to each student. Minimization of the students who are in the 7th to the 10th priority and they are allocated to more than 1 course. Minimization of the surplus student's taking part in one session.
Kaviani et all 2013	Offering a multi objective mathematical model, an innovative algorithm and solving the model by this algorithm , solving the model by simulated annealing	Complete offering of all course units in a week. Offering the Professor's courses in each day in the maximum limit. No interference in professor's schedule. Offered courses in each classes doesn't exceed the possible course number. No interference in venue of the class. Considering the capacity of the class. No interference in student's schedule.	Maximization of using of the available classes in a day. Minimization of not having class by the professors. Minimization of the surplus of the class capacity. Minimization of changing professors among the classes. Minimization of changing of classes for professors. If a course is presented more than once a week all its presentation are planned to be in one class.

Researchers	Approach	limitations	Objective Function
Gunavan et all 2012	Creation of an initial solution by mathematical approach, based on lagranj cut and its improvement by simulated annealing	Offering only one course by one professor. Minimization of the number of the course unit presented by one professor Minimization of the number of the professors allowed to teach one course Planning one presentation of a course in a day. The total number of session made at a time doesn't exceed the total number of available classes. No interference in professor's schedule Offering the total units of a course in a week. No allocation of the courses to the professors without capability of its presentation. Fair distribution of all taught course units by a professor in a week.	Maximization of the total amount of the overall priority to allocate the courses to the professors and days and periods of time to the professors
Kaviani et all 2013	Offering a multi objective mathematical model, an innovative algorithm and solving the model by this algorithm , solving the model by simulated annealing	Complete offering of all course units in a week. Offering the Professor's courses in each day in the maximum limit. No interference in professor's schedule. Offered courses in each classes doesn't exceed the possible course number. No interference in venue of the class. Considering the capacity of the class. No interference in student's schedule.	Maximization of using of the available classes in a day. Minimization of not having class by the professors. Minimization of the surplus of the class capacity. Minimization of changing professors among the classes. Minimization of changing of classes for professors. If a course is presented more than once a week all its presentation are planned to be in one class.

5. The Presented Multi Objective Mathematical Model

The presented Model: In this part we discuss the presented model for course timetabling and 5 groups of objective function and 13 limitations are completely described.

In Table2, the indexes used in model describe completely. Table3, the Parameters used in model describe the Parameters used in model completely. Table 4, describe and mentions to decision variables of model. In Table 5, all of objective functions of model are mentioned and finally in Table 6 all of model's constrains are described.

Table 2 Model's Index

Describe	Index
Number of lesson from 1 o r	i
Number of terms from 1 o 8	j
Number of Time slices from 1 o 5	k

Describe	Index
Number of days from 1 o 7	l
Professors (Faculty members from 1 to n and other from n+1 to m)	p
Number of classes from 1 o s	q

Table 3 Model's Parameter

Describe Parameter	Parameter
Class Capacity	Cq
Lesson Capacity	Si
Toyal time of each class in week	TCq
Toyal time of each Professor in week	Ttp
Quality of each Professor	PRp
Number of timeslices in each day	TSl
Number of timeslices of each class in a week	Tscq
If a Professor can teach a lesson 1 else 0	Eip
If a lesson can be in a class 1 else 0	Oiq
If a Professoris in university in a day 1 else 0	Dlp
If a lesson need to an extra group 1 else 0	Ri

Table 4 Model's Decesion Variables

Describe Variable	Variable
If lesson (i) of term (j) put in timeslice (k) of day (l) teaches by Professor (p) in class (q) 1 else 0	Xijklpq

Table 5 Model's Objective Functions

Type of objective function	Objective functions	Number of formula
MAX	$\text{Max } Z_1=(\sum_{p=1}^{n}\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{l=1}^{7}\sum_{q=1}^{s}\text{Xijklpq})-(\sum_{p=n+1}^{m}\sum_{i=1}^{rS}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{l=1}^{7}\sum_{q=1}^{s}\text{Xijklpq})$	(1)
MIN	$\text{Min } Z_2=\text{Min } (C_q-\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{l=1}^{7}\sum_{p=1}^{m}\sum_{q=1}^{s}\text{Xijklpq} *, \text{Si}), \quad ,\forall q$	(2)
MAX	$\text{Max } Z_3=\text{Max}\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{l=1}^{7}\sum_{q=1}^{s}\text{Xijklpq} * \text{Prp}) \quad ,\forall p$	(3)
MIN	$\text{Min Z4} = \text{Min}\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=4}^{5}\sum_{l=6}^{7}\sum_{p=1}^{m}\sum_{q=1}^{s}\text{Xijklpq}$	(4)
MAX	$\text{Max } Z_5=\text{Max}\frac{\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{l=1}^{7}\sum_{p=1}^{m}\text{Xijklpq}}{\sum_{l=1}^{7}\text{Tsl}} , \quad \forall q$	(5)

Table 6- Model's Canstrains

constraint	For every	Number of formula
$\sum_{i=1}^{r}\sum_{k=1}^{5}\sum_{p=1}^{m}\sum_{q=1}^{s} Xijklpq * Eip * Oiq * Dlp \leq 3$	$\forall$ j, l	(6)
$\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{q=1}^{s} Xijklpq * Eip * Oiq * Dlp \leq 3$	$\forall$ p, l	(7)
$\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{q=1}^{s}\sum_{l=1}^{7}(Xijklpq * Eip * Oiq * Dlp) * 2 \leq Ttp$	$\forall$ p	(8)
$\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{k=1}^{5}\sum_{l=1}^{7}\sum_{p=1}^{m} \mathrm{Xijklpq} * \mathrm{Eip} * \mathrm{Oiq} * Dlp \leq \mathrm{Tsc}_{q}$	$\forall$ q	(9)
$\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{q=1}^{s} \mathrm{Xijklpq} * \mathrm{Eip} * \mathrm{Oiq} * Dlp \leq 1$	$\forall$ k, p, l	(10)
$\sum_{i=1}^{r}\sum_{j=1}^{8}\sum_{p=1}^{s} \mathrm{Xijklpq} * \mathrm{Eip} * \mathrm{Oiq} * Dlp \leq 1$	$\forall$ k, q, l	(11)
$\sum_{i=1}^{r}\sum_{p=1}^{n}\sum_{q=1}^{s} \mathrm{Xijklpq} * \mathrm{Eip} * \mathrm{Oiq} * Dlp \leq 1$	$\forall$ k, l, j	(12)
$Xijklpq \in \{0, 1\}$	$\forall\, i, j, k, l, p, q$	(13)

The above model has 5 group of objective function that includes 3 groups of objective function for maximization and 2 groups of objective function for minimization. This model also has 13 group of limitation.

Objective function 1: It expresses that allocation priority is given to the faculty members, in other words, total hours allocated to the faculty members are more than that of the other professors. Objective function 2 says that the dissipation capacity of the class has to be minimized. In other words, unused and empty classes have to be prevented. Objective function 3: the allocation of the course has to be qualitative and courses are allocated to the professors who have a higher quality parameters. Through quality measurement criteria. Objective function 4: The number of shift forces used has to be minimized, this function follows this object by imposing limitation on the sixth and seventh days of the week and the fifth period of each days. Objective function 5: This function maximizes the use of each class.

Group 1 of limitations: To meet the limitation of the number of the offered courses in a day with less than 3 titles.

Group 2 of the limitations: To meet the limitation of the number of the allocated to one professor in a day with less than 3 titles.

Group 3 of the limitations: The total hours allocated to a professor in week should be less than his attendance, In other words the professor is supposed to available in the allocated hours.

Group 4 of the limitations: the total hours of the allocated courses to one class should be less than its weekly available hours.

Group 5 of the limitations: the schedule of the classes should be with no interference.

Group 6 of the limitations: the professor's schedule should be with no interference.

Group 7 of the limitations: Daily schedule of the courses are in one semesters supposed to be with no interference, for example: if 3 courses are related to the third semester, none of them can't be placed in a common interval of a day.

Group 8 of the limitations: It introduces the type of the decision variables of the model.

6. Numerical example

In this part, the mode of the offered model performance is surveyed by a numerical example. Suppose that we want to timetable 3 courses, 8 semesters, 5 periods of time, 7 days, 4 professors and 2 classes. The tables of the example data are as follows:

In Table 7, data shows that how many student can be in a class it means this table shows the capacity of each class, Like this in Table 8 the capacity of each lesson is shown. In Table 9, Total enable time of each class in seven days of a week is given, like this in Table 10, Total time that each professor is enable to teach in seven days in a week is given. Table 11, show one of given parameters of our model that is about quality of each professor's teaching that is Priority of professors. Table 12, shows the number of time slices of a class in seven days of a week. Table 13, show that a professor can teach which one of lessons it means enableity of professors to teach lessons, like this Table 14, shows enableity of classes to put lessons in them. Finally in Table 15, the days that a professor is in university to teach are shown it means If a Professor is in university in a day 1 else 0.

Table 7 Classes capacity

Classes	1	2
Cq	50	40

Table 8 lesson capacity

Lesson	1	2	3
Si	12	14	9

Table 9 Total time of Classes in a week

Classes	1	2
TCq	40	56

Table 10 Total time of professors in a week

Professors	1	2	3	4
TTp	30	12	20	40

Table 11 Priority of professors

Professors	1	2	3	4
PRp	6	10	5	8

Table 12 Number of timeslices of Classes in a week

Classes	1	2
Tscq	28	20

Table 13 enableity of professors to teach lessons

	Eip	**lessons**		
		1	**2**	**3**
Professors	**1**	1	1	
	2	1	1	0
	3	0	1	1
	4	1	1	1

Table 14 enableity of classes to put lessons

	Oiq	**lessons**		
		1	**2**	**3**
classes	**1**	1	0	1
	2	1	1	0

Table 15 If a Professor is in university in a day 1 else 0

	Dlp	**Professor**	
		1	**2**
Days of week	**1**	1	1
	2	1	1
	3	1	1
	4	1	1
	5	1	1
	6	1	1
	7	1	1

7. Discuss and study findings

Survey of the final answer:

The find timetable after solving the model with data in section 6 and by using LINGO11 software as you consider table 16, the offered model makes a timetable with no interference in the classes and professor's schedule.

Enablity of professors to teach allowed courses, sufficiency of quality measurement criteria, days when professors are available, are all considered.

Table 16 Solution of model by LINGO11

Timeslice	days	professor	class	course
10-12	Theursday	2	1	1
08-10	Theursday	2	2	2
08-10	Wednesday	1	1	3

Quality measurement criteria is considered by giving priority over the professor number 2 in allocation of the courses. The objective function of the maximization use of the classes is made by allocation of the courses to the class number 1 and then allocation to class number 2.

The solution of this problem through LINGO11 software and a computer with this feature:

CPU: Intel (feature: CPU: Intel(R) Core(TM)2 Duo2.10 GHz RAM:4.00 GB

Was done in a second that is a suitable time. The value of the objective function is -872.08 and figure 1 the characteristics of output solution of LINGO exist.

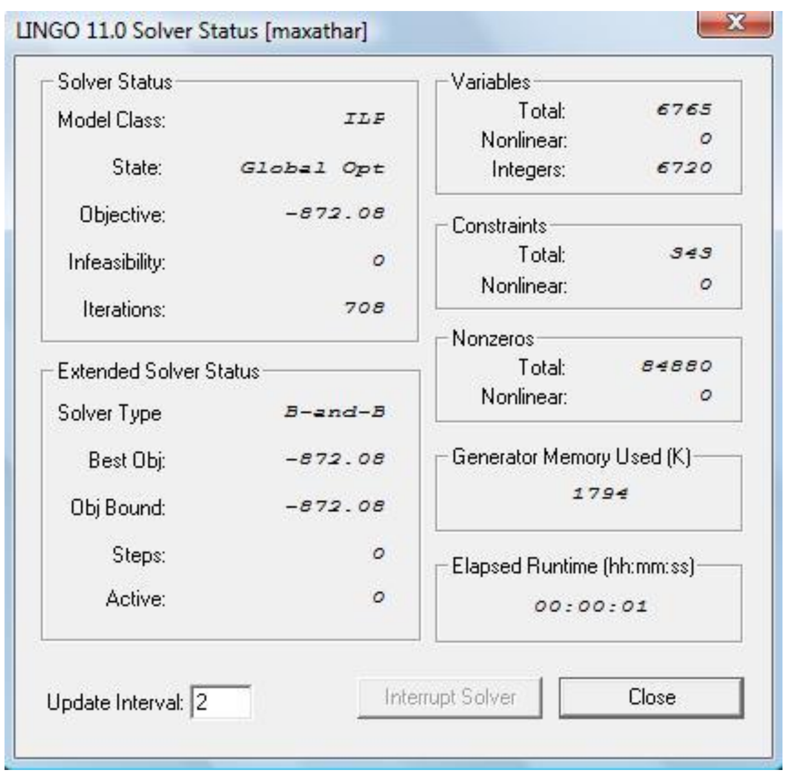

fig 1. The characteristics of output solution of LINGO

8. Conclusion

In this study, we deal with the solution of university courses timetabling through offering a new multi objective mathematical model that has new objective function and new limitations too. The offered model has 5 objective functions including 3 maximization objective functions and 2 minimization objective functions and 8 limitations.

This model tries to meet most of the limitations in the real world through mathematical model. The validity of the mathematical model was examined with solving a numerical number and for its solution LINGO11 software was used .the results indicate that the model can be used in larger problems but due to the numerous limitations and also NP-Hard problem, solving of larger problem is impossible by LINGO11 software. Therefore it is suggested that ultra – innovative procedures are used to solve this model with larger dimensions.

Furthermore, it is better to add more limitations to the model for being more efficient and the model is solved considering different weights for objective functions. These weights can be obtain through a questionnaire, experts ideas and data process.

9. References

Abdullah, S. and Turabieh, H. (2012) 'On the use of multi neighbourhood structures within a tabu-based memetic approach to university timetabling problems', *Information Sciences*, Vol. 191, No. 15, pp.146–168.

Borek, E, K. Marecek, J, J. Parkes, A. Rudova, H. (2010), "Decomposition, reformulation, and dividing in university course timetabling". *Computer and operations research*. Vol. 37, No. 3, pp.582-597.

Daskalaki, S. Birbas, T. Housos, E.(2004), "An Integer Programing Formulation For A Case Study In University Timetabling", *European Journal of Operation Research* , Vol. 153, No. 1, pp.117-135.

Gunawam,A. Kien Ming Ng. Kim LengPoh, (2012), "A hybridized LagrangiaRelaxiation and Simulated Annealing method for the course timetabling problem". *Computer and operation research*, Vol. 39, No. 12, pp. 3074-3088.

Hasanzadeh, M. Bashizadeh, R.(2012) " Optimization of weekly programing of university courses by use of local searches methods, *Mohasebatenarm Journal*, Vol,1. No. 1, pp, 24-31.

Kaviani,M. Shirouyehzad, H. Sajadi, S.M.(2013), "A mathematical model for niversity course timetabling problems by considering multi functions". *Journal of Modelling in Operations Management*, Vol. 3, No. 3/4, pp. 282-295.

Sabar, N.R., Ayob, M., Kendall, G. and Qu, R. (2012) 'A honey-bee mating optimization algorithm for educational timetabling problems', *European Journal of Operational Research*, Vol. 216, No. 3, pp.533–543.

Tong Sun, J. "Simulation Research on university timetabling problem based on new immune GA". © IEEE .

Zanjirifarahani, R. Haji yakhchali, s. (2004), " Integer Model for University course timetabling – a case study", Fourth International conference of industrial engineering, Tehran, 2004.