TIMETABLE OPTIMIZATION USING ARTIFICIAL BEE COLONY ALGORITHM

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ABSTRACT

University course timetabling is something complex. This is because there are some things that must be considered in course timetabling such courses, the availability of the room, the course schedule, availability of the lectures and so on. University course timetabling is Nondeterministic Polynomial-Hard (NP-Hard) which cause the exact resolution is difficult to do while heuristic approaches more logic. Artificial bee colony algorithm is problem independent so this algorithm can be applied to any problem with little adjusment and has ability to search locally or globally in large search spaces using fewer parameters than other approaches like particle swarm optimization or genetic algorithm.

Previous research that use this algorithm in university course timetabling at the onlooker bee phase use random number from 0 to 1 that make randomness getting higher and the solution values are from how much the lecture want to take the course that far from reality. So this research is try to solve university course timetabling with different scout bees phase and real constraint that happen in the real world.

The result from this research are this algorithm can solve university time tabling problem using parameter like number of solutions candidate is 10, limit value is 25000 and maximum cycle number value is 50000. Other information obtained from this research are solution candidates fit value at initialization phase take effect on how many iteration to do to achieve optimal solution and soft constraint handling is not optimal.

Key words : optimization, university timetabling, artificial bee colony, metaheuristic

1. INTRODUCTION

1.1 BACKGROUNDS

Scheduling activities lectures in colleges is complex. This is because there are some things that must be considered in the scheduling of such courses, the availability of the room, the time of execution of the lecture, the existence and availability of the lecturers and so on. The greater number of variables that affect the schedule then it will increase the level of its complexity because it magnifies the chances of the occurrence of an error in the preparation of the schedule. especially the existence of a number of courses that must be allocated in a specific room that has its own criteria.

Techniques that can be done to solve this issue have been introduced in the past 4 decades by researchers in the fields of operational research and artificial intelligence are among the other approach is heuristic-like graph colouring, the technique of constraint-based, case-based reasoning and approach to as local search-based metaheuristic and population-based metaheuristic [1]. This is due to timetabling problems are Nondeterministic Polynomial-Hard (NP-Hard) which causes the exact resolution is difficult to do while approach (heuristic) more logical thing to do.

Methods of approach are of two types . problem dependent heuristics that can only be used on certain issues and problem independent metaheuristic that can be used for various types of problems. Artificial bee colony algorithm is one of population-based metaheuristic algorithms that problems independent as well as have the ability in both local and global search in the search space is great use less number of parameters when compared to other approaches such as particle swarm optimization or genetic algorithms [2].

On previous research conducted Deeptimanta Ojha, Rajesh Kumar Sahoo and Satyabrata Das at the bees ended using a constant whose value is between 0 and 1 and the number of candidate solutions which nectar is derived from the value of teaching interest each candidate solution from lecturer [3]. In this study the constant is replaced by a probability calculation of candidate solutions and the amount of nectar solution comes from the candidates how many candidates the solution violates the hard constraint.

By doing this research produces information expectation is how the performance of artificial bee colony algorithm in solving the problem of scheduling activities and associated costs.

1.2 RESEARCH OBJECTIVES

Based on the issues examined, then a goal to be achieved from this research was to test the performance of artificial bee colony algorithm in the timetabling problem

1.3 LIMITATIONS OF THE RESEARCH

Case studies in Informatics Engineering Department UNIKOM Bandung. With the data set that taken is from the even semester of 2015/2016 academic year (not including entrepreneurship courses).

1.4 SWARM INTELLIGENCE

Swarm Intelligence is one of the techniques of artificial intelligence based on the collective behavior of decentralized system can set itself. Implementation of swarm intelligence is usually in the form of a population that consists of simple agents interacting locally with fellow members of the population and also to interact globally with the environment. (3)

Although usually has no centralized control structure that gave the command of how each agent should act, the interaction between members of the local population tends towards the establishment of a global behavior in [4]. In this case his inteligence swarm is inspired by the behavior of swarms of honey bees in search of food.

1.5 THE BEHAVIOR OF HONEY BEE SWARMS

A simple model of the behavior of swarms of honey bees in search of food leads to the emergence of intelligence collectively than swarms of honey bees which consists of three key components: a food source, the worker bees, the bees are mengganggur and two models of behavior: the deployment to a food source and the abandonment of a food source.

The value of food resources depend on many factors such as proximity to the hive, the concentration of wealth or energy and ease in taking their energy. The advantages of a food source can be represented by a number. Worker bees associated with a particular food source they are exploration. They also carry information from the food source, distance and direction from the hive, the profits from the food source and share the information with a certain probability.

The bees who are unemployed is constantly looking for other food sources are explored. There are 2 types of unemployed: the scout bees, search the environment around the nest to a food source and the onlooker bees waiting in the bee hive and select a food source from the information shared with worker bees. The average number of scout bees with normal condition is 5-10% [5]. The model of this behavior was the one which inspired the artificial bee colony algorithm.

1.6 ARTIFICIAL BEE COLONY ALGORITHM

Artificial bee colony algorithm was conceived by Karaboga and Basturk in 2007 and Karaboga in 2005. The basic idea of this algorithm is to mimic the behavior of foraging (such as exploration, exploitation, deployment, and left) of the honey bee. In this algorithm, it is assumed that each position the food source is a possible solution and the number of nectar from a food source is the quality of the solution. The main steps of this algorithm according to [6] are:

a. initialization: initial population can be defined as P (G = 0) from SN solution (position food source). Where SN indicates a measure of worker bees or scout bees. In addition, each solution x_{ij} (i = 1, 2, ..., SN; j = 1,2, ..., D) is a D-dimensional vector. Here, D is the number of parameters optimization.

b. place the worker bees at a food source in memory and renewing the food source. To generate the position of candidates than the old food sources (x_{ij}) in memory, the memory of the worker bees are updated with the following equations.

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}), \quad j \in \{1,2,\ldots,D\}, k \in \{1,2,\ldots,SN\} \wedge k \neq i, \quad (1)$$

Where v_{ij} is the value of the worthy food source dimension that modified from the value of the food source before (x*ij*) based on a comparison with the values of the food sources neighbor which is randomly selected and Øij is a random number must among |-1, 1 | to adjust the production of food sources around the xij neighbor and represent a comparison of two visually food source position.

c. place the scout bees in search of food sources in memory. Scout bees select value the probability of such food sources (pi) by the following equation.

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n}, \quad (2)$$

Where is the fitness value of fit_i solution is proportional to the amount of nectar food source at that position, SN is measuring worker bees or scout bees. So, the higher the fit_i value the greater the x_{ij} probability for selected.

d. determine which is a decent source of food with scout bees using the equation in step 2. If the value is not increased after a number of experiments that the large number of pre-set, normally called the limit. Now, the worker bees or onlooker bees transformed into scout bees.

e. Send a scout bees to find new food sources. The scout bee process of exploring new food source can be defined with the following equations.

$$x_i^j = x_{\min}^j + rand[0,1](x_{\max}^j - x_{\min}^j), \quad (3)$$

Where x_{min} and x_{max} is the lower limit and upper limit on each of the search scope in each dimension. Here the value of each component in the vector x_i must be among all the range | x_{min}, x_{max} | to reduce the possibility of scout bees leaving search scope.

f. Save the best food sources found so far.

g. check whether the criteria are met or not to stop e.g. maximum number of iterations, if fulfilled, then the process is finished. If not repeat the algorithm again.

2. CONTENTS

This stage will discuss the analysis of issues in this research. The analysis that discussed is the analysis of the problem, an analysis of the system to be built and the analysis methods used to solve the problem in this research.

2.1 Problem analysis

The problem that is discussed in this research is a univsersity course timetabling problem where the preparation of the univsersity course timetabling must obey the restrictions in order for the resulting optimal and useful schedules. This limit is divided into 2 hard constraint i.e. the restrictions that must be met and became arguably the optimal schedule of terms as well as the soft constraint i.e. a limitation should not be fulfilled which became the measure of the quality of the generated schedules.

The hard constraint in this research are as follows:

a. a lecturer can only teach 1 class courses in 1 time slot
b. one room can only be used by 1 class courses in 1 time slot
c. There must be no lectures on Friday prayers

While soft constaint that used in this research is any lecturer have a minimum 1 day off from teaching activities.

So, the main problem in this research are as follows:

a. how to apply artificial bee colony algorithm on the university course timetabling problem
b. how to generate the optimal university course timetabling using artificial bee colony algorithm

2.2 Input Data Analysis

Data sets used in this study consisted of 76 data lecturer, 325 data subjects class, 25 subjects data, 18 lecture rooms data and time 120 slot data.

2.3 Method Analysis

Before doing method analysis used, here the term used in the artificial bee colony algorithm along with match the term commonly used in optimization [7]

Table 1. Artificial Bee Colony Term Table

The term in Artificial Bee Colony	The Optimization Term
food sources	solution
the number of nectar	solution fit value
cycle	iteration
food sources position	solution position
best food sources	best solution

2.3.1 Initialization

Determination of the value of the parameters – parameters algorithm such as population size food sources (SN), the maximum number of iterations (MCN) and limit. If the best food sources of nectar have a number of 1, which means no hard constraint that is violated before the parameter value MCN is reached then the optimization process will be terminated. And the last limit is the maximum size of the experiment is to exploit a food source.

Create the initial population x_{ij} food sources (i = 1,2 ..., SN; j = 1, 2 ..., D) where x_{ij} is the source of food, SN is a measure of population, i is the index of a food source, D is the number of parameters optimization and j is the index of the parameter optimasinya. Every food source and then counted the number of nektar with the formula 1/(1 + B) where B is the number of hard constraint violations.

2.3.2 Worker Bees Phase

Place the worker bees at a food source in memory and generate food source around the food sources that are selected using the equation (1) where a new food source is v_{ij} that are results of modification of the food source before (x_{ij}) based on a comparison with the values of the food sources neighbor which is randomly chosen. $\emptyset_{ij}$ is a random number of bores must among |-1.1 | to control the production of new food sources.

The application of the equation in this case is to change one of the parameters optimization of every source of food with other food sources which is randomly chosen and then counted the number of nektar. If after a number of exchangeable nektar be higher then the exchange of results food sources that are used but otherwise then the old food sources used.

2.3.3 Onlooker Bees Phase

Place the onlooker bees on a food source in memory. Bees calculates the probability of each food source with the equation (2), where i is the index value of a food source and fit is the value of the number of nektar.

The food source with the highest amount of nectar exchange as performed on the stage of worker bees. If after a number of exchangeable nektar be higher then the exchange of results food sources that are used but otherwise then the old food sources are used.

2.3.4 Scout Bees Phase

If the amount of food sources nectar did not experience an increase after a cycle as much as the value of the parameter limit, a new food source is created using the equation (3). Where i is the index value of a food source, j is the value of the index parameter, x_{min} and x_{max}, is the value of the upper limit and lower limit of each parameter optimization scope.

If the value of the cycle is still 1 then there will be done a comparison but the number of nectar food source for long as a comparison is there any increase in value or will not be initialized using the amount of nectar food source at this time.

If the value of the cycle more than 1 do a comparison between the number of nectar with the amount of nectar at the moment, if the amount of nectar current not higher than the amount of the limit value then the long nectar to the dwindling food sources 1 and if it is higher then the value of the limit will remain.

then select the source of the food with the highest amount of nectar to compared to the amount of nectar food source at best, if it is higher then the best food sources are replaced by food source with the highest amount of nectar if not then no changes against the best food source.

2.4 The Test Results

Testing is done in stages starting with 1 semester courses then added courses next semester to the next test. The purpose of this test to find out the extent to which the performance of this algorithm in the problem of scheduling the activities of lecture viewing from the large number of iterations performed, how violations of the soft constraint fit value and how the candidate the best solution after the optimization process is complete.

2.4.1 Testing with 1 Semester Courses

After a few times of experiments optimal results achieved with parameter values the number of candidate solutions = 5, limit = 3500, maximum number of iterations 8000.

Table 2. Testing with 1 Semester Courses Table

Experiment	Iteration	Soft constraint violations	Best Solution Candidate Fit Value
1	8000	12	0.142
2	8000	6	0.083
3	619	18	1
4	1097	4	1
5	6209	11	1
6	8000	8	0.125
7	3502	7	1
8	1442	13	1
9	8000	19	1
10	4954	7	1

The test results it is best to experiment – 4 with many iterations and violation of the soft constraint least.

2.4.2 Testing with 2 Semester Courses

After a few times of experiments optimal results achieved with parameter values the number of candidate solutions, limit = 10 = 10000, 15000 maximum number of iterations.

Table 3. Testing with 2 Semester Courses Table

Experiment	Iteration	Soft constraint violations	Best Solution Candidate Fit Value
1	15000	8	0.03
2	5885	17	1
3	9053	5	1
4	15000	34	0.0156
5	12466	7	1
6	10655	23	1
7	7894	20	1
8	15000	11	0.006
9	8036	12	1
10	13895	18	1

The test results it is best to experiment – 3 with many iterations and violation of the soft constraint least.

2.4.3 Testing with 3 Semester Courses

After a few times of experiments optimal results achieved with parameter values the number of candidate solutions, limit = 10 = 15000, 30000 maximum number of iterations.

Table 4. Testing with 3 Semester Courses Table

Experiment	Iteration	Soft constraint violations	Best Solution Candidate Fit Value
1	8977	8	1
2	23438	10	1
3	30000	9	0.333
4	7106	14	1
5	14615	19	1
6	30000	15	0.5
7	30000	7	0.167
8	30000	11	0.2
9	19328	7	1
10	30000	23	0.25

The test results it is best to experiment – 1 with many iterations and violation of the soft constraint least.

2.4.4 Testing with 4 Semester Courses

After a few times of experiments optimal results achieved with parameter values the number of candidate solutions, limit = 10 = 10000, 15000 maximum number of iterations.

Table 5. Testing with 4 Semester Courses Table

Experiment	Iteration	Soft constraint violations	Best Solution Candidate Fit Value
1	50000	32	0.333
2	50000	17	0.1
3	42035	33	1
4	38185	19	1
5	50000	25	0.125
6	50000	28	0.083
7	50000	14	0.25
8	28364	9	1
9	50000	23	0.2

Experiment	Iteration	Soft constraint violations	Best Solution Candidate Fit Value
10	50000	15	0.167

The test results it is best to experiment – 8 with many iterations and violation of the soft constraint least.

2.5 Test Conclusions

From the testing that has been done can be taken the following conclusions:

a. value of candidate solutions to fit the stage of initialization to be one of the factors that influence in determining the number of the iteration that needs to be done to achieve the optimal solution value.
b. application of the soft constraint still produces a fairly high level of violations.
c. the best test results by using all of the data class subjects is the number of violation soft constraint 9 and value fit candidate best solution 1 which means no hard constraint that is violated. For a parameter that is used is the number of candidate solutions 10, limit the maximum number of iterations 25000 and 50000.

3. CONCLUSION

3.1 Conclusions

Based on the results obtained in this research, retrieved information algorithm artificial bee colony is capable of solving the scheduling of activities and associated with the test results is the number of violation soft constraint 9 and value fit candidate best solution 1 which means no hard constraint that is violated. For a parameter that is used is the number of candidate solutions 10, limit the maximum number of iterations 25000 and 50000.

Other information – information obtained in this study among others the value fit candidate solutions in the initial effect on the number of iterations that must be done to achieve the optimal solution as well as the level of a violation of the soft constraint is applied too high still.

3.2 Suggestions

Based on the results of the research that has been done, still need to do some further study. As for suggestions for further research are:

a. Optimisation of processes on the stage of initialization so that the value of the candidate's initial solution to fit better.
b. application of the soft constraint, so that the resulting schedule is more minimal levels of soft constraint violation.

BIBLIOGRAPHY

[1] A. L. Bolaji, A. T. Khader, M. A. Al-Betar and M. A. Awadallah, "A Modified Artificial Bee Colony Algorithm for Pos-Enrolment Course Timetabling," *Advances In Swarm Intelligence*, vol. 1, pp. 377-386, 2013.

[2] S. Agahian, H. Pehlivan and R. Dekharghani, "Adaptation and Use of Artificial Bee Colony Algorithm to Solve Curriculum-based Course Time-Tabling Problem" *Fifth International Conference on Intelligent Systems, Modelling and Simulation*, pp. 77-82, 2014.

[3] D. Ojha, R. K. Sahoo and S. Das, "Automated Timetable Generation using Bee Colony Optimization," *International Journal of Applied. Information Systems*, vol. 10, no. 9, pp. 38-43, 2016

[4] J. Kennedy and R. C. Eberhart, *Swarm Intelligence*, San Francisco, Morgan Kaufmann Publishers Inc, 2001

[5] D. Karaboga, "An Idea Based on Honey Bee Swarm For Numerical Optimization," *Technical Report-tr06*, vol. 200, 2005.

[6] B. Xing and W.-J. Gao, *Innovative Computer Intelligence : A Rough Guide to 134 Clever Algorithms*, Cham, Springer International Publishing, 2013.

[7] A. L. Bolaji, A. T. Khader, M. A. Al-Betar and M. A. Awadallah, "Tackling University Course Timetabling Problem Using Artificial Bee Colony Algorithm," *MASAUM Network*, vol. 12, pp. 87-96, 2012.