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Human-Dedicated Sustainable Product and Process Design: Materials, Resources, and Energy

Proceedings of the 4th International Conference on Engineering, Technology, and Industrial Application (ICETIA) 2017

Surakarta, Indonesia
13–14 December 2017

Editors
Hari Prasetyo, Nurul Hidayati, Eko Setiawan and Tri Widayatno

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Preface: Human-Dedicated Sustainable Product and Process Design: Materials, Resources, and Energy

Proceedings of the 4th International Conference on Engineering, Technology, and Industrial Application (ICETIA) 2017

International Conference on Engineering, Technology and Industrial Application (ICETIA) is an international conference organized annually by the Engineering Faculty of Universitas Muhammadiyah Surakarta (UMS), known as the biggest private university in Central Java, Indonesia. The 4th ICETIA has been successfully held on 13-14 December 2017 at Alila Hotel, Surakarta, Central Java, Indonesia, attracting more than 300 participants.

This year's conference brought a theme of Human-Dedicated Sustainable Product and Process Design: Materials, Resources, and Energy. It provided an excellent atmosphere for academicians, researchers, industrial professionals and government bodies to share ideas and any breakthrough in terms of materials, resources and energy aiming at establishing sustainable industrial development.

The committee received more than 200 papers, 174 of which were selected and presented in the conference. In these proceedings, the papers are then organized by grouping them into five sub-themes namely: (i) Sustainable Industrial Process and System Optimization, (ii) Product Design, Material and Building Engineering, (iii) Sustainable Infrastructure and Built Environment, (iv) Preservation, Conservation and Water Management, (v) Green Energy and Computing. It is expected that materials presented in these proceedings contribute constructively to create sustainable products and processes beneficial to humans.

Surakarta, Indonesia

7 March 2018

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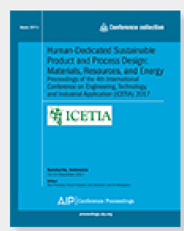

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Hybrid Model of Particle Swarm and Ant Colony Optimization in Lecture Schedule Preparation

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Abstract. Each university has different regulations in making lecture schedule according to the conditions of respective institution. In this study, regulation on lecture scheduling used the maximum limit of credits of lecturer in a day, in which if exceeds the maximum limit, then the schedule of course will be moved on another day. This study attempts to optimize the schedule preparation in each semester by considering the maximum limit of credits of a lecturer in a day. Lecture scheduling is a combination of space, time, and resources. It is categorized into combinatorial optimization group. There are two methods for solving the combinatorial optimization problems, i.e. exact and approximation method. The approximation method consists of two types, heuristics and metaheuristics. The algorithm metaheuristics categories include genetic algorithm (GA), particle swarm optimization (PSO), ant colony optimization (ACO), bee colony optimization (BCO), simulated annealing, and so on. This paper employed metaheuristics approach. Research on the preparation of lecture scheduling using ACO algorithm has been conducted and proven to be able to prepare the lecture scheduling. The ACO algorithm has numbers of parameters that in solving issues, one must manually set a number of parameters by using the Design of Experiments (DoE) tool, which takes time to solve the optimization problem. Hence, to solve the issue, an automated parameter optimization is required. PSO algorithm has fewer parameters compared to the ACO. Therefore, the purpose of this paper is a hybrid between PSO and ACO in preparing lecture scheduling.

INTRODUCTION

The main activity of a Higher Education Institution is related with the educational process. Education is a priority of higher education institutions to form qualified and intelligent students. The objective of education can be achieved through teaching and learning process. This process will run appropriately without any conflict, neither regarding with lecturers nor students, if the schedule is arranged optimally. However, the process of lecture schedule preparation is not a simple as the arrangement of schedule that involves constraints and requires supporting resources. The preparation process may experience many obstacles if the resources owned by a university have minimum facilities, both in terms of infrastructure and human resources. The issues due to the minimum facilities in the field of teaching process are mainly related to the uneven distribution of faculty members in teaching, limited classrooms available, limited space capacity, the absence of constraints in the process of scheduling preparation, and so on. Lecture scheduling preparation cannot be done manually as it involves optimization to solve it. Meanwhile, each university has different regulations in schedule preparation according to the conditions of respective institution. In this research, lecture scheduling regulation used the lecture's maximum limit of credits, if it exceeds the maximum limit in a day, the schedule will be moved on another day. This study attempts to optimize the schedule of each period by considering the maximum limit of credits of lecturer in a day.

Method of optimization in the schedule issue is categorized as combinatorial optimization. There are two methods of approaches for combinatorial optimization, i.e. exact and approximation. Exact method is an optimization completion method that guarantees the achievement of an optimal solution. The weakness of this method is time

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consuming. Conversely, approximation method does not guarantee the optimal completion result. There are two types of approximation methods, heuristics and metaheuristics [1].

To solve the problem of optimizing the preparation of lecture scheduling, this paper employed metaheuristics approach inspired from natural phenomena, such as evolution, animal behavior in search of food, and steel cooling process. Examples of metaheuristics method includes Genetic algorithm (GA), Particle Swam optimization (PSO), Ant Colony Optimization (ACO), Bee Colony Optimization (BCO), simulated annealing, and so on. The methods used were PSO and ACO algorithms. The ACO algorithm shows many parameters in solving a problem of manual procedure that must be done to set a number of parameters owned by ACO algorithm by using Design of Experiments (DoE) tool. To set the parameters manually, the problems must be solved one by one according to the number of parameters. To overcome the issue, an automated parameter optimization is required. PSO is an algorithm of metaheuristics method that has fewer parameters compared to ACO, hence, this paper attempts to hybrid the PSO with ACO in the preparation of lecture scheduling. Many studies have discussed the hybrid of algorithms of metaheuristics method, such as: PSO-Local Search, ACO-GA, and GA-CBR, in the issue of lecture scheduling at higher education institutions.

LITERATURE REVIEW

Lecture Scheduling Preparation

Lecture scheduling preparation is one of the most important administrative activities in Higher Education. In the case of college scheduling, distributing a number of courses allocated to a number of available classrooms and a number of time slots with constraints is required. Constraints consist of two types, namely hard constraints and soft constraints. Hard constraints are the boundaries that must be met on the lecture schedule. Soft constraints are limited on resource allocation and any violation may produce a viable solution but to the extent possible to be fulfilled [2].

Particle Swarm optimization (PSO)

PSO is formulated based on animal behavior, which is the behavior of a flock of birds or fish. Essentially, social behavior (in term of intelligence) of a flock of birds or fish consists of individual actions and influences from other individuals in a population or group. In other words, the behavior of an animal in a herd is influenced by the behaviors of the individual and its flock. The behavior of a group is then adopted into the PSO algorithm.

Terminologies for PSO algorithm are as follows [3]:

- **Population,** a set of candidate solutions that are tested in a single step of time consisting of m particle.
- **Particle**, representing candidate solutions characterized by vector v velocity and vector x position in dimension space D.
- **Evaluation range,** the evaluation period of each candidate solution in one single step of time as in GA, the evaluation range may take more or less time depending on the trial scenario.
- **Fitness function**, measuring the efficacy of candidate solutions provided during the evaluation range.
- **Population manager**, updating velocity and position for each particle according to the main loop of the PSO.

The main loop of Particle Swarm Optimization*,* it can be arranged the following algorithm (Eberhart, Kennedy, and Shi, 1995, 1998) [4]:

At each time step t
For each particle i
For each component j
Update velocity

$$| v_{ij}(t+1) = wv_{ij}(t) + c_p rand(\quad)(x^*_{ij} - x_{ij}) + c_n rand(\quad)(x^*_{ij} - x_{ij}) \tag{1}$$

Then move

$$| x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \tag{2}$$

Ant Colony Optimization (ACO)

Besides the PSO, ACO is also made based on animal behavior that is ant cooperate behavior of ant colony that can find the shortest path from the nest to the food source. Since ants are blind animals, they find the shortest path from the nest to the food source by the help of pheromones. Pheromones are chemicals in ants' body. These pheromones work among ants and the colonies to communicate.

When ants find food, they will move toward the food sources through some randomly targeted paths, and when they move, they leave pheromones. The pheromones will be renewed once the ants have completed through the path [1]. The mathematical model of ant behavior in choosing the targeted path is as follows:

$$p_{ij} = \left\{ \begin{array}{c} \frac{\tau_{i,j}^{\alpha}}{\sum jeN_i^{(k)} \tau_{i,j}^{\alpha}} \\ 0 \end{array} \right\} \quad (3)$$

Where α denotes the degree of importance of pheromones and $N_i^{(k)}$ is the choices had by ant k when the ant is at node I, the neighbor of the ant k at node I will contain all the connecting nodes that are connected directly to node I, except for previous visited nodes. When passing through a node path, an ant k will leave pheromones. The addition and evaporation of pheromones are modeled by the following formula [1]:

$$\tau_{i,j} \leftarrow \tau_{i,j} + \Delta\tau^k \quad (4)$$

$$\tau_{i,j} \leftarrow (1 - \rho)\tau_{i,j}, j \ ; \ \forall(i,j) \in A \quad (5)$$

Optimization

Optimization can be defined as the process of finding the conditions that provide the maximum or minimum of a function. It can be seen from figure 1, in which if a point x^* corresponds to the minimum value of function $f(x)$, the same point will also correspond to the maximum value of the negative of the function $-f(x)$. Thus, without any loss of generality, optimization can be taken to gain mean minimization since the maximum of a function can be found by seeking the minimum of the negative of the same function. Furthermore, there is no single method available for solving all optimization problems efficiently [5].

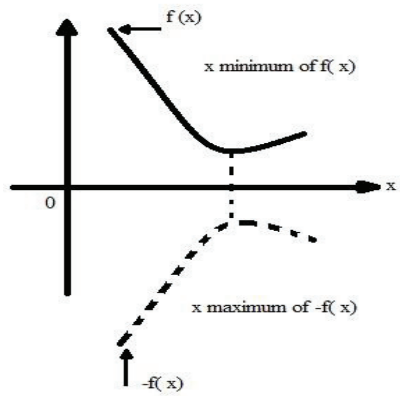

FIGURE 1. Minimum of $f(x)$ is same as maximum $-f(x)$.

RESEARCH METHODOLOGY

The hybrid process of PSO-ACO algorithm consists of three different stages. The main algorithm lies in the PSO algorithm in which it is hybridized with ACO. The stages of PSO-ACO hybrid process are as follows:

- First stage: Set the number of particles and dimensions of problems, and determine the weight of inertia to specify the particle velocity to arrange the schedule by calling on the ant algorithm function.
- Second stage: Set the ACO parameter and perform the ant initialization by performing permutations calling on function “random” and function “optimum1”. Function “random” is used to arrange the schedule with hard constraint hence the combination between course subjects, lecturers, and classrooms will not occur any conflict in the preparation of lecture scheduling. Meanwhile, function “optimum1” is used to optimize the previous schedule arranged by calculating the standard deviation.
- Third stage: Return to the PSO algorithm to optimize the ACO algorithm parameters automatically by employing PSO algorithm.

RESULTS AND ANALYSIS

In this study, the result and analysis of the hybrid between Particle Swarm optimization (PSO) and Ant Colony Optimization (ACO) were done through a case study. The sampling of this study was obtained from a Higher Education Institution. The initial step for the process of preparing lecture schedule was data collection. Data used to prepare the lecture scheduling referred to the data owned by the institution used as the case study of this paper. The data used were in the form of teaching administrative data that included: the number of lecturers, number of existing classrooms, number of laboratories, total number of course subjects, number of study programs, ongoing semesters when this paper was written, and the number of active students. The teaching administrative data are presented in the following Table 1.

Table 1. Teaching Administrative Data

No	Item	Total
1.	Number of permanent lecturers	16
2.	Number of adjunct (non-foundation) lecturers	7
3.	Number of classrooms	4
4.	Number of laboratories	3
5.	Number of study programs	3
6.	Total number of course subjects for 3 study programs	107
7.	Number of semesters (Bachelor’s degree)	3
8.	Number of semesters (Associate’s degree)	2
9.	Total number of active students for all study programs	450

The teaching administrative data were arranged into a teaching information table which contained the lecturers’ information in each study program. This information table was used as the material in preparing the lecture schedule. The following Figure 2 illustrates the information table:

number	course_code	the_name_of_the_course	cridit	the_name_of_lecture	class	semester	number_of_students
1	SI202	Statistik Deskriptif	2	Ariska Kurnia Rachmawati, M.Si. (1)	A	2	20
2	SI204	Pemrograman Terstruktur	3	Gatot Susilo, M.Kom. (2)	A	2	20
3	SI206	Bahasa Inggris 2	2	Drs. Sukris Sutiyatno, M.M, M.Hum. (3)	A	2	20
4	SI207	Pemrograman Berorientasi Objek	3	Sunarni, S.Kom, M.T (4)	A	2	20
5	SI208	Kalkulus 2	2	Ariska Kurnia Rachmawati, M.Si.	A	2	20
6	SI209	Filsafat Ilmu Pengetahuan	2	Drs. Subiyanto, M.Pd	A	2	20
7	SI210	Praktikum Struktur Data	1	Tri Handoyo, M.Kom. (5)	A	2	20
8	SI211	Pengetahuan Bisnis	2	Sugeng Wahyudiono, M.Kom. (6)	A	2	20
9	SI305	Struktur Data	2	Tri Handoyo, M.Kom.	A	2	20
10	SI506	Perakitan Komputer	2	Ali Mahmudi, M.Kom (7)	A	2	20

FIGURE 2. Teaching Information Table

The most important entity to be involved in the lecture schedule preparation is constraint. There were two types of constraints applied in the Higher Education Institution of this study:

- Hard constraint: A lecturer should not be scheduled in different rooms or different subjects at a time, a lecturer must not teach in a row with different subjects, a class must not be conducted at 12.00–01.00 PM, and the teaching process from Monday to Friday is commenced from session 1 at 08.00 to 10.00 AM to until session 3 at 15.00 PM, and on Saturday is from 08.00 to 10.00 AM.
- Soft constraint: A difficult subject is conducted at earlier hours, the distance and classroom from one to another subject should not be too far (for class turnover at adjacent hours).

The hybrid algorithm was developed with Particle Swarm optimization (PSO) and Ant Colony Optimization (ACO) algorithms. The PSO algorithm has been just recently proposed by Kennedy and Eberhart [4] and ACO was first introduced by Dorigo [3].

CASE STUDY

The PSO-ACO hybrid was done using real data in a case study of a university. As a benchmark for PSO-ACO hybrid algorithm, this paper applied standard benchmark function. In testing the PSO-ACO hybrid algorithm, the schedule results were evaluated based on the dispersion of lecturer workload with the standard deviation value of the lecturer's workload by considering the capacity of the room, and compared the results with the manual schedule. The results were seen from the standard deviation of lecturer workload in a day based on the maximal credit load in a day. In this paper, the credits load was adjusted to the standard of education service in Indonesia, in which the maximal credit of a lecturer is 12 credits. It means that a lecturer has teaching day less than 6 credits in the even semester. The results of the spread of workload of lecturers in a day indicated that the lecturers do not teach 3 sessions consecutively in a day. PSO-ACO hybrid algorithm was also compared to ACO and GA-ACO. The tests were performed at the start of the ACO, GA-ACO, PSO-ACO algorithms, the experiments were conducted with several scenarios.

First Scenario: The test on ACO algorithm is based on the value of standard deviation for daily credit load of lecturer, showing that the number of ants was 15 and maximum iteration was 20 has caused the credits load reach more than 6 credits. In this case, the hard constraint was not fulfilled as shown in Table 2 of experiment:

Table 2. ACO Experiment

Code of lecturers	The number of ants and Maximum Iteration		
	5 and 10	10 and 15	15 and 20
1	2,9496	3,5637	1,6432
2	2,3166	2,6394	4,4008
3	2,6583	2,6583	2,3381
4	2,5033	2,9439	3,6697
5	2,9496	3,5637	1,6432
6	3,9707	2,2286	2,9269
7	1,3292	2,5626	1,8348
8	3,8859	3,4496	3,9875
9	1,3292	2,5626	1,8348
10	3,3714	3,3116	2,4833
11	2,7142	1,6021	1,6021
12	2,3166	2,6394	4,4008
13	3,4881	3,4881	2,5626
14	1,5055	1,5055	2,3381
15	6,4005	6,2743	5,1543
16	1,0328	1,0328	1,6330
17	6,4005	6,2743	5,1543
18	2,6583	2,6583	2,3381
19	0,8165	0,8165	0,8165
20	3,8859	3,4496	3,9875
21	3,3714	3,3116	2,4833
22	2,6583	2,6583	2,3381
23	2,3166	2,6394	4,4008

Second Scenario: The test on GA-ACO algorithm is based on standard deviation value of lecturers' daily credits load. It indicated that the number of ants, which were 15 and maximum iteration was 20 have caused daily credits load of lecturers reach beyond maximum, less than 6 credits. The hard constraint was not fulfilled as shown by Table 3 of experiment below.

Table 3. Experiment GA-ACO

Code of lecturers	The number of ants and Maximum iteration		
	5 and 10	**10 and 15**	**15 and 20**
1	2,5100	2,3452	2,5100
2	3,8687	3,1885	3,2506
3	2,3381	3,2042	2,3381
4	3,5024	4,3205	3,3267
5	2,5100	2,3452	2,5100
6	3,4303	3,1252	3,1252
7	2,0412	2,2286	2,5626
8	2,6646	3,4496	2,3452
9	2,0412	2,2286	2,5626
10	3,3714	3,6009	3,1885
11	0,9832	2,0412	2,2286
12	3,8687	3,1885	3,2506
13	1,9408	1,1690	2,4833
14	1,5055	1,9664	1,9664
15	3,3116	4,8339	4,9160
16	1,6330	1,0328	1,6330
17	3,3116	4,8339	4,9160
18	1,3663	1,3663	1,3663
19	0,8165	0,8165	0,8165
20	2,6646	3,4496	2,3452
21	3,3714	3,6009	3,1885
22	1,3663	1,3663	1,3663
23	3,8687	3,1885	3,2506

Third Scenario: The test on PSO-ACO algorithm is based on standard deviation value of lecturers' daily credit load, which demonstrated that the number of ants, which were 15 and maximum iteration of 20 have caused the average number of lecturers' daily credits load is merely a course. In accordance with this result, the hard constraint was fulfilled as shown in Table 4 of experiment below.

Table 4. Experiment of PSO-ACO

Code of lecturers	The number of ants and Maximum iteration		
	5 and 10	**10 and 15**	**15 and 20**
1	2,3452	2,5100	2,5884
2	2,9269	4,3089	4,1191
3	2,3381	1,9664	1,5055
4	4,2740	3,3267	3,5590
5	2,3452	2,5100	2,5884
6	2,6394	3,1885	2,6394
7	2,2286	1,3292	1,3292
8	2,8107	3,5637	3,6742
9	2,2286	1,3292	1,3292
10	2,4833	3,4881	1,4720
11	0,9832	2,2286	2,2286
12	2,9269	4,3089	4,1191
13	2,2286	2,5626	2,2286
14	1,5055	1,5055	1,9664
15	4,3089	5,5287	6,0800
16	1,6330	1,6330	2,0656
17	4,3089	5,5287	6,0800
18	2,0656	2,3381	2,0656
19	0,8165	0,8165	2,0656
20	2,8107	3,5637	0,8166
21	2,4833	3,4881	3,6742
22	2,0656	2,3381	1,4720
23	2,9269	4,3089	2,0656

CONCLUSION

From the scenarios simulated in this study, it can be concluded that the results of ACO algorithm and GA-ACO algorithm based on case study in the same place, with the number of ants of 15 and the number of iterations of 20 for each algorithm, obtain the scenario of daily credits load of lecturer that is almost similar to the average credit load according to regulation on Higher Education, which is less than 6 credits. Even though, although the amount of credits loads meets the regulatory standard of daily credit load of lecturer, the conflict still occurs in which one lecturer is scheduled to have two classes at the same time. Different results obtained from PSO-ACO hybrid algorithm with the number of ants of 5 and the number of iterations of 10. The result of daily credit load scenario is less than 6 credits and there is no conflict in this schedule, it means that the combination of various parameters of ant and number of iteration is able to overcome the harsh obstacles, and the PSO is able to optimize the schedule created by ACO algorithm. However, the PSO-ACO hybrid algorithm still has a weakness in a random function of the ACO algorithm since the process is still done manually.

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