Subject scheduling system using Ant Colony Optimization at MAN 3 Palembang

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ABSTRACT

In preparing the subject schedule, it must be done correctly because all teaching and learning activities are between teachers and students. So far, the subject scheduling process at MAN 3 Palembang is carried out manually so that clashes often occur between subjects and teachers who teach can teach in different classes at the same time resulting in the teaching and learning process being slightly disrupted. One of the commonly used metaheuristic algorithms for solving optimization problems is the Ant Colony Optimization algorithm, also known as the ant algorithm. The implementation of this application is to create schedules using the Ant Colony Optimization algorithm thus beneficial for operators who create schedules in school. This system can also be applied in cases where schedules conflict, namely teachers teaching in the same room and teachers teaching the same subject teaching in different classes at the same hours. This makes it easier for operators to create schedules so that they can be resolved more easily and quickly. This application was successfully developed into a subject scheduling system and managed to run optimally. From the results of implementing scheduling using the Ant Colony Optimization algorithm method used in compiling subject rosters, it can help the MAN 3 Palembang school which previously carried out schedule preparation manually.

1. Introduction

A schedule is a series of meetings that run simultaneously. The meeting here is a meeting that brings together various sources Examples include people, rooms, etc [1]. Scheduling problems are one of the most common combinatorial optimization problems. In everyday life, scheduling problems in education are not new.

In general, scheduling problems can be divided into several types, such as university academic level placement, elementary and secondary school scheduling, exam scheduling, transportation scheduling, sales arrangement, goods delivery, etc [2]. In every educational institution there is a process for scheduling teaching and learning activities which is carried out at the beginning of each academic year to organize all these activities.

In preparing the subject schedule, it must be done correctly because all teaching and learning activities are between teachers and students. So far, the subject scheduling process at MAN 3 Palembang is carried out manually so that clashes often occur between subjects and teachers who teach can teach in different classes at the same time resulting in the teaching and learning process being slightly disrupted.

When scheduling subjects, you must pay attention to the availability of the number of teachers, classes and subjects available, each teacher's teaching time may not be the same, etc. so that an optimal subject schedule will be very difficult to obtain.

Alamsyah be explained the nature of the problem of scheduling subjects for schools because there are many parts that must be considered. In preparing a schedule, several components that need to be considered include students, teachers, classrooms, and time, while taking into account certain constraints and conditions to avoid conflicts in the schedule, such as class overlaps, teacher conflicts, and others [3].

One of the metaheuristic algorithms that is commonly used to solve scheduling optimization problems is the Ant Colony Optimization algorithm or commonly known as the ant algorithm [4], [5], [6]. The Ant Colony Optimization algorithm is an algorithm initially inspired by the behavior of ants. The Ant Colony Optimization algorithm has evolved into various other types of algorithms, such as the Ant System Algorithm, Elitist Ant System Algorithm, Rank-Based Ant System Algorithm, Max-Min Ant System (MMAS) Algorithm, and Ant Colony System Algorithm [7].

Based on the description above, this research will optimize the subject scheduling system using Ant Colony Optimization at MAN 3 Palembang. It is hoped that with the Ant Colony Optimization method, the subject scheduling system can be better formulated in completing subject schedules with the best solution.

2. Literature Study

a. Scheduling

Scheduling is a decision-making process that has an important role in manufacturing processes and production systems as well as in the information processing environment. Scheduling is the allocation of appropriate time resources and space for the smooth completion of organizational tasks [8]. Scheduling is also found in transportation and distribution in industry. Scheduling is used to decide which processes should run as well as when and for how long the process will run.

b. Optimization algorithms

Optimization algorithms are also defined as a branch of applied mathematics and numerical analysis which discusses optimization with single, multiple or possibly even conflicting criteria.

Raio be explained optimization can be defined as a process of finding conditions that provide the maximum and minimum values of a function [9]. Sugioko be explained "Optimization is a scientific discipline in mathematics that focuses on systematically obtaining minimum or maximum values from a function, opportunity or finding other values in various cases [10].

The result of an optimization process is a set of inputs that make objective functions produce optimal values (which can be maximum or minimum). From several existing optimization algorithms.

c. Ant Colony Optimization

Reddy & Bijwe be explained Ant colony optimization (ACO) is a type of metaheuristic algorithm. Metaheuristic algorithms are algorithms with the ability to solve non-linear, complex problems, handle confusing variables, and handle multi-objective optimization problems [11].

d. How Ant Colony works

Fernandez be explained defines the work of the Ant Colony algorithm as follows [12]:

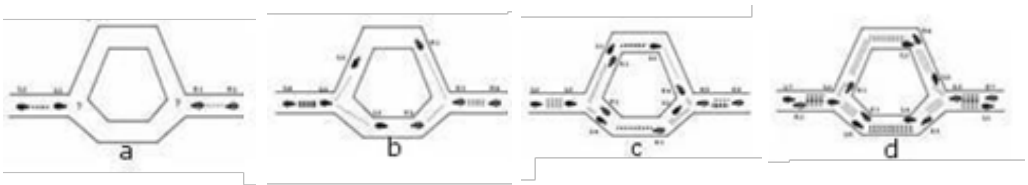


Fig. 2. Ant behavior[9]

At first, the ants wandered around randomly. When the ants find a different path, for example arriving at an intersection, they will start to determine the direction of the road randomly as in Fig. 1a. Some ants choose to walk up and some choose to walk down, as in Fig. 1b. When they find food they return to their colony while signaling with a trail of pheromones.

Because the path taken via the bottom route is shorter, the bottom ants will arrive first assuming the speed of all ants is the same as in Fig. 1c. The pheromone left by the ants on the shorter path will have a stronger aroma than the pheromone on the longer path as in Fig. 1d.

3. Methodology

a. Data Collection

Data collection carried out in this research was as follows:

- Observation

  This observation is data collection carried out in direct meetings at MAN 3 Palembang.
- Interview

  This interview was conducted through face-to-face interviews and questions and answers with the relevant parties, namely the head of the curriculum and teachers, in order to obtain information for the purposes of this research.
- Literature study

  A literature study is conducted by collecting data related to the content being developed. Data obtained from various sources in the form of journals, papers, documentation books, articles, the internet, and other information related to the subject scheduling system that will be built.

b. Framework

The planning for this research framework was carried out through the following stages:

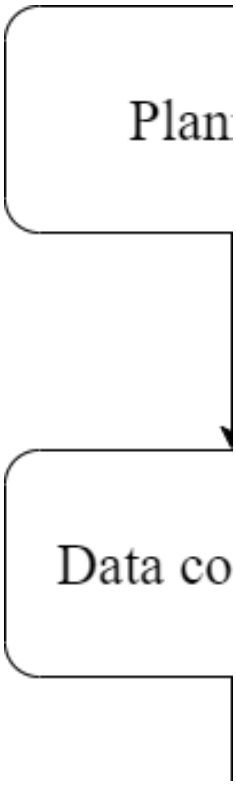


Fig. 3. Research Framework

- Planning

  The planning phase begins by defining the objectives of the Subject Scheduling System, focusing on minimizing scheduling conflicts and optimizing the use of resources such as classrooms and teachers. The scope of the project is determined by identifying the subjects, teachers, classrooms, and constraints, including teacher availability, room capacities, and student groups. A detailed timeline is created with milestones to ensure the project progresses smoothly, while resources such as team members and tools are allocated. Additionally, potential risks, such as conflicts in teacher availability or inefficient scheduling, are assessed, and strategies for mitigation are developed.

- Data Collection

  In the data collection phase, relevant information is gathered, including details about subjects, teacher schedules, classroom availability, and student groupings. This data is essential for developing the scheduling system and must also account for specific constraints, such as teachers being unavailable at certain times, room capacities, and any subject-specific requirements (e.g., lab usage). Once the data is collected, it is organized in a structured format, such as a database or spreadsheet, to ensure ease of use when inputting it into the scheduling system.

- System Planning

  System planning focuses on designing the architecture of the scheduling system. This includes developing the user interface (frontend) and the backend logic, where the Ant Colony Optimization (ACO) algorithm will be implemented to generate optimal schedules. The ACO algorithm will be customized to consider the various constraints and optimize the schedule based on available resources. Additionally, the system must be compatible with existing school management systems to facilitate seamless data input and output. User roles, such as administrators, teachers, and students, are defined to manage permissions and ensure smooth system operation.

- Testing

  The testing phase involves a comprehensive assessment of the system's functionality. Initially, unit testing is performed on individual components of the system, such as data input forms, the ACO algorithm, and the user interface. Integration testing follows to ensure that all components work together seamlessly. Performance testing evaluates the efficiency of the ACO algorithm, especially when handling large datasets, while usability testing ensures that the interface is intuitive and easy to use. Constraint testing checks whether the system respects all scheduling requirements, such as teacher and room availability. Finally, the system undergoes final validation by generating test schedules to ensure it meets all defined requirements before deployment.

4. Result and Discussion

a. Test Scenario

System Implementation using the application that is being tested, after going through the scheduling process using the Ant Colony Optimization Algorithm, the output will be obtained, namely the value of hard constraint violations, soft constraint violations, and subject schedules. The limits or constraints are divided into two, namely hard constraints and soft constraints. An example of a hard constraint used in this research is:

1) Teachers cannot choose the classes they will teach.

2) In one learning day, the teacher cannot choose the teaching and learning time.

The soft constraints used are the teaching schedule preferences of each teacher, such as when the teacher cannot be present to teach because there is something else that makes the teacher unable to attend to teach. The input that can be entered into the application before the scheduling process runs is the desired number of ants and iterations. In this experiment, several different values will be entered for each parameter so that optimal scheduling results can be found, where the value of actual soft constraint violations will be sought. The initial values of the parameters used in the trials in this scheduling are available in Table 1.

Table 1. System Parameters Initialization

Parameters	Grade
Alfa	0.01
Beita	0.01
Rho	0.03
Q (constant)	1
m (number of ants)	10
iteration	5

b. Test Results

For testing results, each parameter value will be changed. Changing parameter values is carried out in order to obtain the best results from the experiment whose values will be determined randomly. And the criteria for getting the best results is that the value of the hard constraint must be 0 and the soft constraint must be no more than 10. The following are the best results obtained in testing available in Table 2.

Table 2. Experiment 1 with alpha value 0.01

No (Experimental results)	Best ant (Best features)	Soft constraint (No schedule)
1	9th ant iteration 5	10
	Total soft constraint	10

First experiment in Table 2. performed using default parameters. In this data test, we will see which ants produce the smallest soft constraint violation values. The example in the first experiment produces 1 best ant. The first example is the 9th ant of the fifth iteration with a total of 10 soft constraint violations and a total of 10 soft constraint violations. The experiment in Table 2 shows that the best results were obtained without changing the alpha parameter with a total violation of the soft constraint 10.

Table 3. Experiment 2 with beta value 4

No (Experimental results)	Best ant (Best features)	Soft constraint (No schedule)
1	3rd ant iteration 3	5
	Total soft constraint	5

At the experiment in Table 3, shows that the best results by replacing the beta parameter value to 4 with 5 violations of the soft constraint.

Table 4. Experiment 3 with rho value 0.5

No (Experimental results)	Best ant (Best features)	Soft constraint (No schedule)
1	4th ant iteration 1	5
2	5th ant iteration 2	4
	Total soft constraint	9

At the experiment in Table 4. shows that the best results are obtained by changing the rho parameter value to 0.5 with a total of 9 constraints.

Table 5. Experiment 4 with Q value 5

No (Experimental results)	Best ant (Best features)	Soft constraint (No schedule)
1	2nd ant iteration 1	3
2	3rd ant iteration 4	7
	Total soft constraint	10

In the experiment in Table 5. shows that the best results are obtained by changing the Q parameter value to 5 with a total violation of the soft constraint of 10.

Table 6. Experiment 5 with 10 ants

No (Experimental results)	Best ant (Best features)	Soft constraint (No schedule)
1	8th ant iteration 5	6
	Total soft constraint	6

In the experiment in Table 6. shows that the best results are obtained without changing the ant parameter values with a total violation of the soft constraint of 6.

Table 7. Experiment 6 with iteration value 5

No (Experimental results)	Best ant (Best features)	Soft constraint (No schedule)
1	5th ant iteration 5	9
	Total soft constraint	9

Table 7 shows that the best results were obtained without changing the iteration parameter values with a total of 9 soft constraint violations.

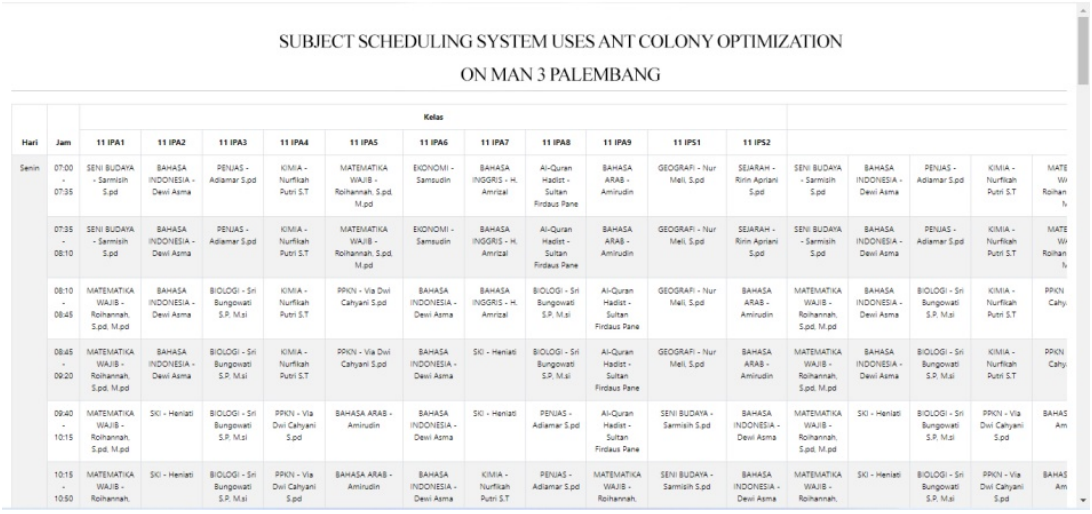
After processing the data with each changed parameter value and subject data of 100 schedules that will be scheduled with the system, the results obtained are:

a) Alpha = 0,01
b) Beta = 4
c) Rho = 0,50
d) Q = 5
e) Ants = 10
f) Iteration = 5

Hard constraint violations have reached 0 in each generation, which is very good because hard constraints cannot be violated.

Unplaced or the condition where the schedule request is not included in the scheduling timetable is 0. This means that all schedules can be scheduled well even though there are still some violations of the soft constraints.

The following are the results of subject scheduling that have been successfully generated using the parameters that have been tested:



SUBJECT SCHEDULING SYSTEM USES ANT COLONY OPTIMIZATION
ON MAN 3 PALEMBANG

Hari	Jam	Kelas										
		11 IPA1	11 IPA2	11 IPA3	11 IPA4	11 IPA5	11 IPA6	11 IPA7	11 IPA8	11 IPA9	11 IPS1	11 IPS2
Senin	07:00 - 07:35	SENI BUDAYA - Sarmisih S.pd	BAHASA INDONESIA - Dewi Asma	PENJAS - Adiamar S.pd	KIMIA - Nurfikah Putri S.T	MATEMATIKA WAJIB - Rolhannah, S.pd, M.pd	EKONOMI - Samsudin	BAHASA INGGRIS - H. Amrizal	Al-Quran Hadist - Sultan Firdaus Pane	BAHASA ARAB - Amirudin	GEOGRAFI - Nur Meli, S.pd	SEJARAH - Rirn Apriani S.pd
	07:35 - 08:10	SENI BUDAYA - Sarmisih S.pd	BAHASA INDONESIA - Dewi Asma	PENJAS - Adiamar S.pd	KIMIA - Nurfikah Putri S.T	MATEMATIKA WAJIB - Rolhannah, S.pd, M.pd	EKONOMI - Samsudin	BAHASA INGGRIS - H. Amrizal	Al-Quran Hadist - Sultan Firdaus Pane	BAHASA ARAB - Amirudin	GEOGRAFI - Nur Meli, S.pd	SEJARAH - Rirn Apriani S.pd
	08:10 - 08:45	MATEMATIKA WAJIB - Rolhannah, S.pd, M.pd	BAHASA INDONESIA - Dewi Asma	BIOLOGI - Sri Bungowati S.P, M.si	KIMIA - Nurfikah Putri S.T	PPKN - Via Dwi Cahyani S.pd	BAHASA INDONESIA - Dewi Asma	BAHASA INGGRIS - H. Amrizal	BIOLOGI - Sri Bungowati S.P, M.si	Al-Quran Hadist - Sultan Firdaus Pane	GEOGRAFI - Nur Meli, S.pd	BAHASA ARAB - Amirudin
	08:45 - 09:20	MATEMATIKA WAJIB - Rolhannah, S.pd, M.pd	BAHASA INDONESIA - Dewi Asma	BIOLOGI - Sri Bungowati S.P, M.si	KIMIA - Nurfikah Putri S.T	PPKN - Via Dwi Cahyani S.pd	BAHASA INDONESIA - Dewi Asma	SKI - Heniati	BIOLOGI - Sri Bungowati S.P, M.si	Al-Quran Hadist - Sultan Firdaus Pane	GEOGRAFI - Nur Meli, S.pd	BAHASA ARAB - Amirudin
	09:40 - 10:15	MATEMATIKA WAJIB - Rolhannah, S.pd, M.pd	SKI - Heniati	BIOLOGI - Sri Bungowati S.P, M.si	PPKN - Via Dwi Cahyani S.pd	BAHASA ARAB - Amirudin	BAHASA INDONESIA - Dewi Asma	SKI - Heniati	PENJAS - Adiamar S.pd	Al-Quran Hadist - Sultan Firdaus Pane	SENI BUDAYA - Sarmisih S.pd	BAHASA INDONESIA - Dewi Asma
	10:15 - 10:50	MATEMATIKA WAJIB - Rolhannah,	SKI - Heniati	BIOLOGI - Sri Bungowati S.P, M.si	PPKN - Via Dwi Cahyani S.pd	BAHASA ARAB - Amirudin	BAHASA INDONESIA - Dewi Asma	KIMIA - Nurfikah Putri S.T	PENJAS - Adiamar S.pd	MATEMATIKA WAJIB - Rolhannah,	SENI BUDAYA - Sarmisih S.pd	BAHASA INDONESIA - Dewi Asma

Fig. 4. Scheduling Result

5. Conclusion

Based on the research that has been carried out, several conclusions can be drawn, namely :

1. This application was successfully developed into a subject scheduling system and managed to run optimally
2. The performance of the Ant Colony Optimization algorithm in solving the scheduling problem is highly optimal, as no subject collisions occur. Additionally, for soft constraint violations related to no subject schedule collision, the number of violations is minimal, the lowest are only 3 violations.

References

[1] A. Jain, D. S. Jain, and D. P. K. Chande, "Formulation of Genetic Algorithm to Generate Good Quality Course Timetable," *Int. J. Innov. Manag. Technol.*, vol. 1, no. 3, 2010.

[2] D. Nugraha and R. Kosala, "A comparative study of evolutionary algorithms for school scheduling problem," *J. Theor. Appl. Inf. Technol.*, vol. 67, no. 3, 2014.

[3] R. W. Alamsyah, "Optimalisasi penjadualan multi constraint menggunakan logika fuzzy= Multi Constraint Scheduling Optimization Using Fuzzy Logic," *Sains dan Sibernatika*, vol. 17, no. 2004, 2004.

[4] M. Boru, "Algoritma Ant Colony Optimization untuk Optimasi Penjadwalan Mata Kuliah," *Telekontran J. Ilm. Telekomun. Kendali dan Elektron. Terap.*, vol. 7, no. 2, pp. 136–144, 2019.

[5] I. Noviasari, A. Rusli, and S. Hansun, "Penerapan Algoritma ACO untuk Penjadwalan Kuliah Pengganti pada Perguruan Tinggi (Studi Kasus: Program Studi Informatika, Universitas Multimedia Nusantara)," *Ultim. InfoSys J. Ilmu Sist. Inf.*, vol. 9, no. 2, pp. 79–85, 2018.

[6] A. Silalahi, M. M. Santoni, and A. Muliawati, "Pembuatan Aplikasi Penjadwalan Mata Kuliah Menggunakan Algoritma Ant Colony Optimization (Studi Kasus: Program Studi Informatika Fakultas Ilmu Komputer Universitas Pembangunan Nasional Veteran Jakarta)," *Inform. J. Ilmu Komput.*, vol. 16, no. 3, pp. 148–155, 2020.

[7] P. K. Tiwari and D. P. Vidyarthi, "Improved auto control ant colony optimization using lazy ant approach for grid scheduling problem," *Futur. Gener. Comput. Syst.*, vol. 60, pp. 78–89, 2016.

[8] G. Mould, J. Heizer, and B. Render, "Production and Operations Management: Strategies and Tactics (3rd Edition).," *J. Oper. Res. Soc.*, vol. 45, no. 5, 1994, doi: 10.2307/2584398.

[9] C. C. Raio *et al.*, "Can emergency medical services personnel identify pneumothorax on focused ultrasound

examinations?," *Crit. Ultrasound J.*, vol. 1, no. 2, 2009, doi: 10.1007/s13089-009-0016-5.
[10] A. Sugioko, "Perbandingan Algoritma Bee Colony dengan Algoritma Bee Colony Tabu List dalam Penjadwalan Flow Shop," 2013.
[11] S. Surender Reddy and P. R. Bijwe, "Efficiency improvements in meta-heuristic algorithms to solve the optimal power flow problem," *Int. J. Electr. Power Energy Syst.*, vol. 82, 2016, doi: 10.1016/j.ijepes.2016.03.028.
[12] M. S. Fernandez, Antonio, Eko Handoyo, "Pembangunan Aplikasi Penyusunan Jadwal Kuliah Meggunakan Algoritma Semut," *Tek. Elektro Fak. Tek. UNDIP*, 2011.