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Modelling of Subject Scheduling Systems Using Hybrid Artificial Bee Colony Algorithm

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Abstract: A common schedule problem found in colleges is the positioning of courses in a certain space and time. This placement process often encounters barriers that must be met so that there is no imbalance in the school schedule. One of the problems that often arise is the placement of class capacity that does not match the course requirements. In this study, the researchers used the Artificial Bee Colony Hybrid Algorithm (HABC) to construct course schedules efficiently at the college. The objective of the research was to develop a course scheduling system using the HABC algorithm by combining the Engineering of Artificial Bee Colony (ABC) and genetic algoritms, especially on the crossover process to better address the schedule problems. The research procedure used is to design and implement a course scheduling system using the Hybrid ABC algorithm. The results of the research demonstrate that the Hybrid ABC algorithm is effective in generating optimal course schedule schedules, in line with time limits, room needs, and lecturer requirements and can automate course schedule processes, saving time and resources, while ensuring optimal schedules.

Keywords: Artificial Bee Colony Hybrid Algorithm, Metaheuristic, Modelling, Simulation

INTRODUCTION

In the growing digital age, scheduling has become a common problem that is frequently faced in various educational institutions, including colleges. Amid the complexity of schedules involving a variety of courses, lecturers, and rooms, course scheduling plays a crucial role in determining the smoothness of the teaching learning process. However, we often encounter the challenge of drawing up efficient schedules, where conflicts between existing schedules can hinder students and lecturers in organizing their study time and teaching tasks. This situation has a negative impact on all parties involved, and leads to discomfort and in optimism in the academic process.
(Fajrianto et al., 2022).

In addition to scheduling conflicts, a common schedule problem found in colleges is the placement of courses into certain spaces and time slots. This placement process often faces barriers that must be met so that there is no collision. One of the problems that often arise is the placement of class capacity that does not match the course needs. Especially on compulsory courses taken by many students in one semester, limited class capacity often causes students to be unable to enroll because classes are already full. As a result, students will have to wait a few more semesters to be able to take the courses, which hampers their study progress. In addition, scheduling collisions also often occur between two elective courses or even between compulsory courses to be taken in the same semester. This is usually due to non-optimal scheduling, where scheduled schedules overlap. In addition to these barriers, the existing scheduling system also has other shortcomings, namely the irregularity of the course load on a daily

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basis. Sometimes, courses are gathered in one particular day, making it difficult for students to organize their study time and distribute their attention evenly. (Fahlevi, 2018).

In order to address these problems, research was conducted to draw up an optimal course schedule in order to avoid scheduling conflict. Researchers used the Artificial Bee Colony Hybrid Algorithm in college course scheduling(Zhu et al., 2022). Artificial Bee Colony is an optimization algorithm that has proven to be effective in solving optimal problems (Christopher & Ginting, 2019). The algorithm is inspired by the search-feeding behavior of the ants' colony and is combined with the crossover operator of the genetic algorithms. In this study, the Hybrid Artificial Bee Colony algorithm was developed to enhance optimization in the AI Algorithm (Sağ & Kahramanli, 2017). The crossover operators of Genetic Algorithms are used to enhance the exchange of information between bees in the process of searching for scheduling solutions (Sari et al., 2022; L. Zhou et al., 2020). To test the performance of the Hybrid Artificial Bee Colony algorithm, a number of functions are used to compare it with some of the other algorithms commonly used in scheduling. Barbosa's research (2022) showed that the Hybrid Artificial Bee Colony algorithm was able to better accuracy, durability, and speed compared to the other algorithms tested (Barbosa-p, 2022). Analysis by Boufflet (2022) also supports this finding, showing that the Hybrid Artificial Bee Colony algorithm has stability, and better optimization performance (Boufflet et al., 2022; Xiang et al., 2021; Zheng et al., 2023). The results of comparisons with other algorithms will provide a better understanding of the advantages and weaknesses of the Hybrid Artificial Bee Colony algorithm in the context of college course schedule. Research on scheduling issues has also been carried out to address the problem of multi-criteria scheduling on the schedule on the switching of electric cars, the establishment of the minimum vertical on the route of vehicles, and also the modification of crossovers to obtain accuracy in simulations (Akay et al., 2021; Banharnsakun, 2023; B. Zhou & Zhao, 2023). Thus, the research aims to develop optimum course schedule using the Artificial Bee Colony Hybrid Algorithm with the aim of improving the efficiency and quality of the course schedule system at the university. By implementing the Hybrid Artificial Bee Colony algorithm, it is expected to produce optimum schedules by minimizing conflict, maximizing resource use, and meeting set limits.

LITERATURE REVIEW

Subject Scheduling

In a system, scheduling plays an essential role in achieving efficiency and performance efficiency. The more complex a system is, the more crucial the importance of effective scheduling. Scheduling is the process of drawing up a schedule or sequence of processes that are essential in a matter (Comert & Yazgan, 2023). It involves plotting the order of work and allocation of resources, both in terms of time and facilities, for each operation to be completed. Overall, scheduling is a strategic aspect of planning and organizing time and resources. According to the Great Dictionary of Indonesian Language (KBBI), scheduling originates from the word "schedule" which refers to the division of time based on a plan of arrangement of work sequence, lists or tables of activities, or activity plans with a detailed division of execution. Scheduling itself is the process, method, and action to schedule or include activities in a schedule (Bhaskoro et al., 2021). With scheduling, the time of an activity can be well regulated, the process time can be minimized, the waiting time of the customer can be reduced, and the use of facilities, labor, and equipment can be done efficiently. Good scheduling will have a positive impact, among other things, operating costs and low delivery time in the context of production problems, customer satisfaction of timely transportation services, smooth activity processes in line with the agenda, as well as elimination of schedule collisions in the process of teaching learning activities in the university educational environment. Therefore, scheduling is an essential measure for better future planning. The main function of scheduling is to ensure the efficacy of the planning process in accordance with the scheduled time (Ardiansyah & Junianto, 2022).

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Artificial Bee Colony algorithm

This algorithm has a basic idea of the evolutionary process that occurs in living beings and considers the outcome of each evolution to be something better or optimal. One of the algorithms that belong to the category of evolutionary computing is Swarm intelligence (Xiang et al., 2021; Xu & Wang, 2022). Swarm intelligence can be defined as collective intelligence or group intelligence, which is intelligence derived from the behavior of a group. In particular, the Artificial Bee Colony algorithm is inspired by the behavior of honey bees to find food sources (Sari et al., 2022). A colony of bees can navigate a distance of up to 10 km and can also move in all directions simultaneously in search of more than one source of food. In the search for food the bee has three working divisions that have an important role in each of its parts, the working group is:

1. Employed bees, bees that belong to this group of working bees have the task of finding food sources in certain regions that have been visited before. Each working bee has a different area in obtaining its source of food.
2. Onlooker bees, bees that belong to the search group have the task of collecting information from each working bee then gather with all the search bees and then exchange information with each other and then make decisions based on the information provided by the working bee.
3. Scout bees, bees that belong to a group of spy bees are tasked with finding food sources in certain areas that have never been visited before.

Some steps on the Artificial Bee Colony algorithm for scheduling problems are as follows:

1. Early Population Initialization, in its theory, the initialization of populations carried out in the Artificial Bee Colony algorithm was formed randomly.
2. Employed Bee phase, at the bee employee stage, searches for new food sources (V_m) that have more nectar around the food source (X_m) in their memory. They search for neighbor's food sources and then evaluate their profitability (fitness). For example, they can determine neighbor food sources (V_m) as follows.

$$V_{mi} = X_{mi} + P_{mi}\,(x_{mi} - x_{ki}) \tag{1}$$

where X_k is a randomly selected food source, (i) is the index of the randomly chosen parameter and Pmi is the random number in the range $[-1,1]$. At that point, the details of the process need to be explained. V_{mi} is a real number that is converted into a whole number by rounding it. On the other hand, w is the number of classrooms. If not, then V_{mi} is counted again using other random P_{mi} values. This situation is a modification of the "employed bee phase" due to the special structure of the course schedule issues. Once a new food source is produced, its fitness is calculated and harsh selection is applied between X_m and V_m. Employed Bees phase projections on course scheduling issues are the process of changing scheduled time slots and possibly classrooms from a lecture hour. Changes are checked first. If there is a conflict, it is unacceptable and X_{mi} remains unchanged.

3. Onlooker Bee
   Move the onlooker bees toward food sources and determine the amount of nectar. In this step, the onlooker bee selects a food source using probability calculation and obtains a new food source in the area of the food source that has been selected through the formula,

$$P_i = \frac{fit_m(\vec{x}_m)}{\sum_{m=1}^{SN} fit_m(\vec{x}_m)} \tag{2}$$

Once the feed source for the observer bee is selected probabilistically, the environmental source V_m is determined using the equation (2), and its fitness value is calculated. As with the working bee phase, a sharp selection is applied between X_m and V_m. Therefore, more data is recruited to richer sources and positive feedback behavior appears.

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4. The scout will look for new food sources to replace the food sources left by the onlooker bee based on random searches (stage 1), the unemployed bee who chooses its food source randomly is called the navigator. Working bees whose solution cannot be enhanced through a number of pre-determined trials, determined by the user of the ABC algorithm and called "limits" or "negation criteria" here, become spies and the solution is abandoned.
5. Note the best food sources that have been found so far. The best population is the population with the lowest fitness score.

Here is the algorithm of the artificial bee colony:

1. Initialization
Initialize the food source and evaluate the nectar amount of food source (fitness).
Send the employed bees to the current food source.
iterasi = 0

2. **Do while** *(the termination condition are not met)*

3. // Employed Bee
For each *employed bee Find a new food source in its neighborhood*
Evaluate the fitness of the new food source
Apply greedy selection
End for

4. Calculate the probability P for each food source

5. //Onlooker Bee
For each *onlooker bee*
while *(Current number of onlooker Bee i <= Sn/2)*
if *(rand () < P)*
Send onlooker bees to the food source of i employe bee
Find a new food source in its neighborhood
Apply greedy selection of the new food source
i=i+1
else
i=i+1
i=mod((i-1), Sn/2) +1
End if
End while

6. //Scout Bee

7. Memorize the best solution
Iteration = iteration+1;
End while

8. Output the best solution of the new food source

A literature review is a critical, analytical summary and synthesis of the current knowledge of a topic. It should compare and relate different theories/research, findings, and so on, rather than just summarize them individually. It should also have a particular focus or theme to organize the review. In this section, the researcher can describe some of the related previous studies. Researchers can review the gaps in the research, then it can be used as a basis for research to be carried out

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METHOD

Research Method

In building a system there are many phases to be considered. One of these aspects is the design of the system. Before a system design is thrown in the form of a program, it is best to create a logical plan of the system. Here is a scheme draft developed in the course schedule using the Hybrid Artificial Bee Colony algorithm:

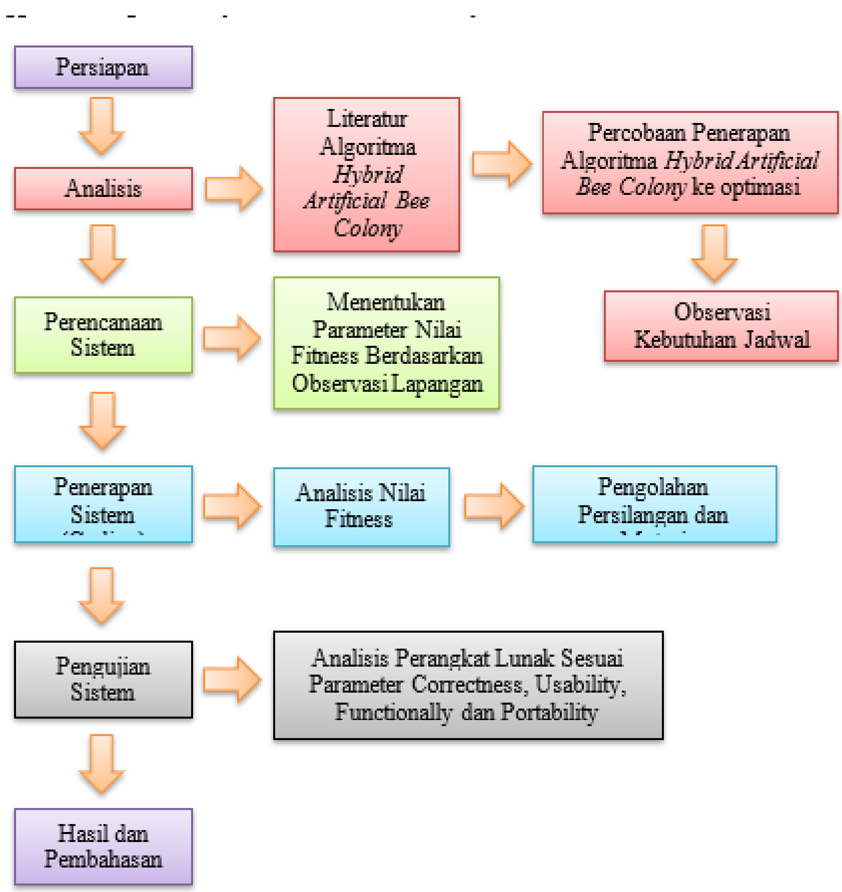

Fig. 1 Procedure and work order

The first stage is preparation that includes initial planning in the form of a research plan. This plan contains general research steps. The second is field observations and literature studies of the hybrid artificial bee colony algorithm (analysis) required to obtain an overview of the research object, namely the course schedule. For this purpose, observations were conducted at one of the colleges. Literature research was then conducted by enriching readings about the artificial hybrid bee colony algorithm, both through internet media, journals, contemporary research, as well as relevant books. Then the next stage is system design, system application (coding), system testing, and result writing and discussion. The method on the artificial bee colony hybrid algorithm has several stages and repeats. In this case, the method on the creation of class schedules has several stages as in Figure 3.3, namely Determining Early Population, Employed Bee, Onlooker bee, Croosover, Scout bee, Best Solution. The system design of this survey begins from the input that is the initial process of the system to the final output to be obtained. Information system design is the representation, planning, and creation of sketches or arrangements of several elements separated from one integral and functional unity. The system design includes course data input, lecturer data, class data, day data, time data and hybrid artificial bee colony algorithm parameters.

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Data Analysis

Data analysis phase is the initial processing of data that will be used as an input file in an automated course schedule application. The input data that is structured follows the dataset format and consists of several components, such as initial data initiation, class capacity, and some matrix related to course schedule information. In this study, optimum solutions will be sought for the scheduling of courses of the S1 Mathematics Studies Program T.A. Ganjil 2023/2024. In this context, the researchers compiled a data set consisting of 2 classes, where each class had the same course, except for elective courses that only had 1 class. In addition, each class has a different teacher. The researchers uploaded this data collection to Kaggle, then downloaded it and used the Pandas library to read the file in CSV format. The CSV structure is as follows.

Table. 1 CSV Name Data Structure in Microsoft Excel

Kelas	**Kode_MatKul**	**Nama_MatKul**	**Pengajar_1**	**Pengajar_2**
A	USU1101	Agama Islam	LIDA	LIDA
A	MAT1101	Matematika Dasar	Prof. Dr. Elvina Herawati, M.Si	M. Romi Syahputra, M.Si
A	MAT1102	Statistika	Dr. Sutarman, M.Sc	Dr. Suryati Sitepu, M.Si
…	…	…	.	…

The following will show the capacity of the many classrooms used in the strange semester lectures that are divided into 3 slots for each day. The following table depicts the class capacity lines for equal and bizarre semesters. The constraints to be adhered to, through the functional objectives to be attained by the program established. Courses are planned over a period of one semester with a total of timeslots of 14/week. Here are the notes used in automatic scheduling:
i = planned event
t = timeSlot is available
r = is the room used.
c = room capacity

Here are the variables of this study.

$$x_{itr} = \begin{cases} 1 \\ 0 \end{cases} \quad (3)$$

1 if the event of I is scheduling in time t , dan room r. In creating a course schedule model, the hard and soft barriers that influence the schedule process must first be defined. The hard and soft barriers that will be defined on the scheduling model in the Mathematics Studies Program are adjusted to the conditions that exist in actual circumstances. Hard constraint is a rule that must be followed by the model that will be created. When a solution violates a hard constraint, it is declared not feasible. The first hard constraint is related to the rule that every course that has been defined as an event must be scheduled on an existing timeslot. You can see the equation below.

$$\sum_{i=1}^{I}\sum_{t=1}^{T}\sum_{r=1}^{R} X_{itr} = 1 \quad (4)$$

Where x_{it} is an event that is scheduled on the timeslot. The next boundary is related to schedule clashes. Each planned event should not have the same timeslot of each other, can be modeled as the equation below.

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RESULT

Here is the code of the Python program to complete the scheduling of the course major of the University of North Sumatra Mathematics for a strange semester with the academic year 2023-2024 using the particle swarm optimization algorithm.

```
import numpy as np
import pandas as pd
from pyswarm import pso
# Read course data from CSV file
course_data = pd.read_csv('course_data.csv')
# Extract relevant data columns
courses = course_data['Course Code'].tolist()
professors = course_data['Course Professor'].tolist()
slots = course_data['Course Slot'].tolist()
rooms = course_data['Course Room'].tolist()
# Define number of courses and time slots
num_courses = len(courses)
num_slots = max(slots) +
# Define schedule array
schedule = np.zeros((num_courses, num_slots), dtype=int)
# Define objective function for the PSO algorithm
def objective_function(position, *args):
    course_data = args[0]
    schedule = np.reshape(position, (num_courses, num_slots))
    fitness = 0
    for i in range(num_courses):
        for j in range(num_slots):
            if schedule[i][j] == 1:
                fitness -= 1
                for k in range(num_slots):
                    if k != j and schedule[i][k] == 1:
                        fitness += 1
                for l in range(num_courses):
                    if l != i and schedule[l][j] == 1 and professors[i] == professors[l]:
                        fitness += 1
                if rooms.count(rooms[i]) > 1:
                    fitness += 1
    return fitness
# Define the bounds for the PSO algorithm
lb = np.zeros(num_courses * num_slots)
ub = np.full(num_courses * num_slots, num_courses - 1)
# Run the PSO algorithm
xopt, fopt = pso(objective_function, lb, ub, args=(course_data,), swarmsize=100, maxiter=100)
# Reshape the solution to the schedule format
schedule = np.reshape(xopt, (num_courses, num_slots))
# Print the final schedule
print(schedule)
```

The program can show the following variables: matacular code, course time slot, classroom and instructor. Here is one explanation of the school schedule given for Monday:

1. At room 2202 there is a MAT4158A course with the instructor Prof. Dr. Elvina Herawati M.Si / Princess Khairiah Nasution M.S.
2. At room 2203 there are MAT3136A courses with Drs instructors. Rosman Siregar M.Si / Yan Batara Son of S.Si.

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3. In the room 2204 there is a MAT3126B course with the instructor Prof. Dr. Saib Suwilo M.Sc / Aghni Syahmarani M.Si
4. At room 8201 there is a MAT3126A course with the instructor Dr. Princess Khairiah Nasution M.Si.
5. At room 8202 there are MAT3137A courses with instructor Parapat Gultom M.SIE Ph.D / Erwin M.Si.

The program defines class schedule as a list of days, times, and classes, and defines fitness function as a measure of how well the schedule meets the constraints. The fitness function calculates the number of conflicts in a schedule, where conflict occurs when two classes are scheduled at the same time, and returns a reverse fitness score compared to the amount of conflict. The simulation results on the determination of class schedule are shown on the table 2.

Table. 2 The Simulation of Algorithm

Slot_time	Room	Day	Slot_time	Room	Day
1	2202	Monday	1	8201	Wednesday
2	2202	Monday	2	8201	Wednesday
3	2202	Monday	3	8201	Wednesday
1	2203	Monday	1	8202	Wednesday
2	2203	Monday	2	8202	Wednesday
3	2203	Monday	3	8202	Wednesday
1	2204	Monday	1	2202	Tuesday
2	2204	Monday	2	2202	Tuesday
3	2204	Monday	3	2202	Tuesday
1	8201	Monday	1	2203	Tuesday
2	8201	Monday	2	2203	Tuesday
3	8201	Monday	3	2203	Tuesday
1	8202	Monday	1	2204	Tuesday
2	8202	Monday	2	2204	Tuesday
3	8202	Monday	3	2204	Tuesday
1	2202	Tuesday	1	8201	Tuesday
2	2202	Tuesday	2	8201	Tuesday
3	2202	Tuesday	3	8201	Tuesday
1	2203	Tuesday	1	8202	Tuesday
2	2203	Tuesday	2	8202	Tuesday
3	2203	Tuesday	3	8202	Tuesday
1	2204	Tuesday	1	2202	Friday
2	2204	Tuesday	2	2202	Friday
3	2204	Tuesday	3	2202	Friday
1	8201	Tuesday	1	2203	Friday
2	8201	Tuesday	2	2203	Friday
3	8201	Tuesday	3	2203	Friday
1	8202	Tuesday	1	2204	Friday
2	8202	Tuesday	2	2204	Friday
3	8202	Tuesday	3	2204	Friday
1	2202	Wednesday	1	8201	Friday
2	2202	Wednesday	2	8201	Friday
3	2202	Wednesday	3	8201	Friday
1	2203	Wednesday	1	8202	Friday
2	2203	Wednesday	2	8202	Friday

3	2203	Wednesday	3	8202	Friday
1	2204	Wednesday			
2	2204	Wednesday			
3	2204	Wednesday			

The PSO algorithm produces an initial particle population, where each particle represents a candidate schedule. The particle is randomly initialized by position and speed, which represents the potential solution and direction and speed of its movement through the solution space. In each iteration of the PSO algorithm, a particle is evaluated for its fitness, and its position and speed are updated according to the principle of attraction-attracting to the best position so far found by the particle itself (personal best) and the best positions found by that particle. (terbaik global). The best personality is updated when a particle finds a new position with a better fitness than its current personal best. The global best is updated as a particle finds new positions with better matches than the current global best. Algorithms end after a certain number of iterations or when a certain fitness threshold is reached. The best particles in the final population are returned as a solution. Overall, the PSO algorithm provides an efficient and effective way to schedule courses while meeting barriers such as time slots and class conflicts. It is a useful tool for university administrators and teachers who need to make schedules for a large number of classes and students.

DISCUSSIONS

Based on the research carried out, a simulation of matacular scheduling segmentation was obtained that was adjusted to the weight of the number of students and the class capacity of each component. Changes in the amount of the barrier value can be quickly determined by the results of segmentation quickly. this research needs to be developed when the qualification of the docent becomes a barrier by adjusting the condition of the doctor to enable the subject.

CONCLUSION

Based on the results of research conducted on the modeling of course scheduling using the hybrid algorithm Artificial Bee Colony (ABC) resulted in matacular distribution with no occurrence of mataculary division imbalance, this occurs because in the crossover process is limited to the capacity of space and class time for each lecturer capable of the course. The Python program implemented in this study has shown how matacular distribution is optimal.

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