The Comparison between Dragonflies Algorithm and Fireflies Algorithm for Court Case Administration: A Mixed Integer Linear Programming

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Abstract. This article focuses on case assignment which is one of the most significant tools in case management to improve efficiency of judicial system. The effectiveness of judicial system depends greatly on the efficient and timely manner of court case operation, especially in criminal cases where suspects are hold in prison on remand. To ensure the rule of law, the preferred system in the court of justice is the one that is predictable and consistent. However, one of the building blocks to such goal is the nature of litigation which is unpredictably time consuming. In this paper, a Mixed Integer Linear Programming (MILP) is selected to address the issue of case assignment in the court of justice. The computational experiments are also reported to evaluate its solution. The two techniques of metaheuristic method are used to find optimal solution of the assignment problem that are called Dragonflies Algorithm (DA) and Fireflies Algorithm (FA). The result shows that DA is more effective in finding an optimal solution to the problem of court case assignment than of the FA.

1. Introduction
The preferred system in the court of justice is the one that is predictable and consistent to ensure the rule of law [1]. Even though justice administration and case assignment are routine works in judicial system, it is repeatedly reported that litigation is unpredictably time consuming. In the last decade, due to the change in constitutional law of Thailand which requires a full quorum of judges to be seated at a hearing, the caseload in the court of justice is dramatically increase. A proposal has been made to increase system efficiency through case management, court-annexed mediation, and digital audio testimony recording system [2]. However, the major challenges still remain which are to define the right case to be assigned to the right justice team and to allocate appropriate time for delivering the court decision. It is proposed in this article that a math model in the form of mixed integer linear programming MILP can be a helpful way to adopt a measure to develop the judicial system.

Generally, in planning the working system in an organization, the coordination of workers and tasks is a major consideration that reflects the efficiency of the company. The Mixed Integer programming (MILP) used in the examination proctor assignment problem by Takeshi Koide where staffs are assigned as proctors in the regular examination period [3]. Julia Rieck et al. [4] applied the
project scheduling problems subject to general temporal constraints using MILP model and domain-reducing processing techniques. David Bredström et al. [5] used MILP model for barge transport planning on the river Rhine. The planning solved the supply chain management of Omya’s production of Norwegian high quality calcium carbonate slurry, supplied to European paper manufacturers. Christodoulos A. Floudas [6] applied the scheduling of chemical processing systems based on MILP approaches which improved the computational efficiency in the solution of MILP problems. However, the use of MILP model in juridical problem is still limited.

The main purpose of metaheuristic optimizations is to find optimal solution for NP-hard problem which the algorithm of metaheuristic optimizations is made of a random number that moves in a wide feasible solution to solve several optimization problems. Because some functions may have discontinuities, and thus derivative information is not easy to obtain, the metaheuristic optimization reduces the time in finding the exact solution or the good solution in the problem. Popular methods for assignment problem includes; Ant Colony Optimization (ACO) [7], Firefly Algorithm (FA) [8-9], and Dragonfly algorithm (DA) [10].

In this paper, the objective function to maximize the overall effectiveness is used in the MILP optimization model. The objective of assignment problem includes N cases that must be assigned to M teams where each team has the competence to do all cases. However, due to personal ability, case specification or other reasons, each team may spend different time for minimize or maximize with the objective of assignment problem.

The rest of the paper proceeds as follows: Section 2 presents the mathematical model for assignment problem of the case assignment in the court of justice. The objective function uses the MILP optimization by using two metaheuristic optimizations to find an optimal solution. The computational results and discussion about the effectiveness of the proposed metaheuristic algorithms are provided in Section 3. Finally, section 4 presents the summarizes of our conclusions.

2. The Mathematical Model for Case Assignment Problem

2.1 The definition of the problem

In order to simplify the presentation of the approach, it is assumed in this the mathematical model that:

- There are fixed numbers of justice panels (3, 4, or 5) in one court and one judge can only be in one panel.
- All of the justice panels have the same expertise.
- One case is being assigned to only one panel.
- No interdependencies exist between each case.
- Each case required difference time limit depending on the nature of the case.
- The minimum effective time for delivering a decision for one case is one day. Whereas the maximum effective time for delivering a decision is 90 days which represents the longest time period where a person can be held in prison on remand.

The formulation of problem, \( C \) is index set for cases assignment, \( P \) is index set for justice panel, \( c \) is each case assignment, \( \mu_c \) effective rate for case assignment, \( L_c \) and \( U_c \) are lower bounds and upper bounds on justice time. Next, \( MT \) is maximum time for justice deadline \( T_{cj} \) is assignment of case \( c \) to the right justice and \( X_{ij} \) is a binary decision variable. For determine the problem, a set \( C = \{1, 2, ..., n\} \) of \( n \) cases has been filed to the court of justice where a set \( P = \{1, 2, ..., m\} \) of \( m \) are available justice panels forming justice teams.

2.2 The objective function of problem

The MILP model is represented as follows:
maximize \quad Z = \sum_{i=1}^{n} \sum_{j=1}^{m} \mu_i \cdot T_{ij} \quad (1)

Constraints:
\[ \sum_{i=1}^{n} T_{ij} \leq MT; \quad \forall \ j \leq m \quad (2) \]
\[ T_{ij} - X_{ij} \cdot U_i \leq 0; \quad \forall \ i \leq n, j \leq m \quad (3) \]
\[ T_{ij} - X_{ij} \cdot L_i \geq 0; \quad \forall \ i \leq n, j \leq m \quad (4) \]
\[ \sum_{j=1}^{m} X_{ij} \leq 1; \quad \forall \ i \leq n \quad (5) \]
\[ X_{ij} = \begin{cases} 1, & \text{if case } i \text{ is selected to justice } j; \\ 0, & \text{otherwise}; \end{cases}, \quad \forall \ i \leq n, j \leq m \quad (6) \]

It is assumed that the effectiveness rates of cases administration are \( \mu_1, \mu_2, \ldots, \mu_n \), respectively. The objective function according to equation (1) for the above problem is defined to the overall effectiveness for the judicial mode. The constraint in equation (2) is the total time spent on a sequential of case for each justice team is less than or equal to \( MT \). The constraint in equation (3) is called upper bound \( U_i \) for the time spent on each selected case \( i \) and it is no more than upper bound. The constraint in equation (4) is called lower bound \( L_i \) for the time spent on each selected case \( i \) and it is no more than lower bound. Define \( X_{ij} \) as a binary decision, let a number of 1 if case \( i \) is selected and assigned to justice team \( j \) and let a number of 0 if otherwise in constraint according equation (5) and (6).

2.3 The metaheuristic optimization

2.3.1 Inspiration. In applying the method, the cases are assigned to justice panels considering the maximum time available. The cases are sorted into a list with the amount of time allocated for each case. Then the first case in the list is assigned to the justice panel. The workstation used for carrying out the result is equipped with 2.40 GHz processor, 4.00 GB of RAM, and the system used Microsoft 7. Scilab free software was used to carry out simulation of the proposed algorithm. The number of cases for experimental parameters was 50 and the number of justice team for experimental parameters was 3, 4 and 5. The optimization method of maximizing effectiveness of case assignment in court of justice in this paper used two techniques of metaheuristic methods; Firefly algorithm (FA) and Dragonfly algorithm (DA). Adopting from the behaviour of fireflies, the flashing light is viewed as associated with the objective function to be optimized. Thus, makes it possible to formulate new optimization algorithm so called Firefly algorithm (FA). For the Dragonflies algorithm, the interesting fact about dragonflies is their unique swarming behaviour. Naturally, dragonflies swarm in hunting and migration. Such behavior can be depicted to form optimization algorithm called Dragonfly algorithm (DA).

2.3.2 The Firefly algorithm for problem (FA) and The Dragonfly algorithm for problem (DA). The FA technique was firstly introduced by Yang in 2008 [9]. The FA is generally used in solving continuous optimization in NP-hard problems. Algorithm 1 illustrates the FA pseudo code. The second
metaheuristic method that is being used in this paper is DA. The DA is proposed firstly by Seyedali Mirjalili in 2016 [10] from the inspiration of static and dynamic swarming behaviors of dragonflies. These two swarming behaviors are very similar to the two main phases of exploration and exploitation in optimization using meta-heuristics. The objective swarming behaviors are reflected in the algorithm of DA. The algorithm of DA is presented in Algorithm 2.

Algorithm 1. Pseudo code of the FA

1: Define the objective function \( f(x) \);
2: Initialize the firefly population \( x = x_1, x_2, \ldots, x_n \);
3: Define the light absorption coefficient \( \gamma \);
4: for each firefly \( x_i \) in the population do
5: Initialize light intensity \( I_i \);
6: end
7: repeat
8: for each firefly \( x_i \) in the swarm do
9: for each other firefly \( x_j \) in the swarm do
10: if \( I_i > I_j \) then
11: Move firefly \( x_i \) toward \( x_j \);
12: end
13: Attractiveness varies with distance \( r \) via \( \exp(-\gamma r) \);
14: Evaluate new solutions light and update intensity;
15: end
16: end
17: end
18: Rank the fireflies and find the current best;
19: until termination criterion reached;
20: Rank the fireflies and return the best one;

Algorithm 2. Pseudo code of DA

1: Initialize the dragonflies population;
2: Initialize step vectors
3: while the end condition is not satisfied do
4: Calculate the objective values of all dragonflies;
5: Update separation weight, alignment weight, cohesion weight, food factor and enemy factor;
6: Calculate separation, alignment, cohesion, food source and enemy factor;
7: Update velocity vector;
8: Update position vector;
9: else
10: Update position vector;
11: end if
12: Check and correct the new positions based on the boundaries of variables;
13: end while

2.3.3 The metaheuristic optimization to solve problem. The proposed metaheuristic optimization to solve the problem is described as follows:

Input: Index set of \( C \) and \( P \). For each case \( c \in C \), effectiveness rate is \( \mu_c \) and maximum time for justice team deadline is \( MT_c \). Lower and upper bounds on decision times are \( L_c \) and \( U_c \), respectively.

For assumption, the effectiveness rates for each case \( (\mu_1, \mu_2,...,\mu_n) \) are in decreasing order.

Step 1: Set \( c = 1 \), and set \( Z_c = T^*_c = 0, MT_i = MT \), for each \( c \in C \) and \( i \in P \).

Step 2: Find justice \( i \in P \), and \( MT_i \) if \( U_i \leq MT_i \) then \( T^*_c = U_c \) and update \( MT_i = MT_i - T^*_c \). Next, go to step 4 and go to step 3 where otherwise.

Step 3: If \( L_c \leq MT_i \) then \( T^*_c = MT_i \) and \( MT_i = MT_i - T^*_c \) and go to step 4.
Step 4: If $MT_z = 0$ for all $z \in M$ or $c = n$ then go to step 5. Otherwise, let $c = c + 1$ and return go to step 2.

Step 5: Calculate $Z^* = \sum_{c=1}^{n} \mu^*_{c} T_{c}^*$ and stop.

Output: The best solution of total effectiveness is $Z^*$ and $T_{c}^*$ is the global maximize point of problem used by FA and DA.

In the experimental tests, for example, we solve the effectiveness problem with the number of 7 cases for experimental parameters and the number of justice team for experimental parameters was 3. The total time available (deadline) for justice decision is $MT = 90$. Therefore, we generated parameters $\mu, U_i$, and $L_i$ by following two problem with a uniform distribution e.t. in the form $P1$: $\mu = (1,90), L_i = (1,30), U_i = (1,90)$ and $P2: \mu = (1,90), L_i = (1,60), U_i = (1,90)$. Table 1 shows the case study using $P1$ the data set into part 1 and the total effectiveness into part 2, respectively.

| Table 1. The case study | Table 2. The results of FA and DA for the problem |
|------------------------|-----------------------------------------------|
|                        | Example data set                               | $P$  | $(n:m)$ | DA | FA |
|                        | $c$  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | Effectiveness | % Deviation | Effectiveness | % Deviation |
|                        | $i$  | 1  | 2  | 3  | -  | -  | -  | -  | Avg. Time (s) | Avg. Time (s) |
|                        | $\mu_c$ | 27 | 25 | 20 | 15 | 13 | 10 | 8  |                 |                |
|                        | $L_i$ | 2  | 6  | 13 | 28 | 16 | 29 | 17 |                 |                |
|                        | $U_i$ | 85 | 61 | 29 | 34 | 59 | 32 | 48 |                 |                |
|                        | $T_{c_i}$ | 71 | 33 | 15 | 87 | 49 | 30 | 9  |                 |                |
|                        | $c$  | 1  | 2  | 3  | 4  | 5  | 6  | 7  |                 |                |
|                        | $i$  | 2  | 1  | 3  | 1  | 3  | 2  | 1  |                 |                |
|                        | $T_{c_i}$ | 71 | 33 | 15 | 87 | 49 | 30 | 9  |                 |                |

The assignments described above by executing step 2 – 5, step 5: Calculate $Z^* = (27 \times 71) + (25 \times 33) + (20 \times 15) + (15 \times 87) + (13 \times 49) + (10 \times 30) + (8 \times 9) = 5356$ and stop. Next, the output of total effectiveness $Z^* = 5356$ is the best solution found by FA or DA.

3. Results and Discussion

The computational and effectiveness results are generated using FA and DA. Table 2 shows the total available CPU time (seconds) in finding an optimal solution where 25 problem instances were generated. The number of cases for experimental parameters was 25 with the number of justice team for experimental parameters was 3, 4 and 5. Percent deviation is $100\%$[Optimal solution - FA or DA solution]$/[Optimal solution]$. For 25 instances, the average of percent deviation is $\sum_{i=1}^{25}$ [percent deviation]/25. Experimental results show in Table 2 articulate that time of optimal solutions and percent deviation for maximize effectiveness of DA are better than those of fast FA. In the results, it can be seen that when the number of cases was 50 and the number of justice team was 3 for experimental parameters, $P1(50:3,4,5)$ the average of percent deviation of DA is 0.01, 0.02, and 0.01 and total available time of DA is 603.81, 716.05, and 833.30, respectively. It can be seen that the result is better than the fast FA. Furthermore, in the $P2(50:3,4,5)$ the average of percent deviation of DA is 0.05, 0.09, and 0.01 and total available time of DA is 715.97, 828.45, and 952.46 respectively. The result is also better than fast FA in measuring performance.
4. Conclusion
In this paper, the proposal to increase effectiveness of court case assignment through a MILP is presented. A metaheuristic algorithm is used to find the optimal solution for assignment problem. Experimental results show that time of optimal solutions and average of percent deviation for maximize of DA are better than those of fast FA. The performance of DA is better than that of FA for maximizing effectiveness of case assignment in court of justice.

In the future work, it will be useful to improve metaheuristic optimization for the fast computing and defining parameter optimization for the assignment problem in legal fields.

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