Scheduling algorithms for an expatriate assignment using vertex coloring of graph

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Abstract. Scheduling system for an expatriate assignment needs an effective and efficient way to be designed since the expatriates reside outside their countries to do their assignments in very limited time. The problem of this scheduling system is quite complicated as the expatriates usually work in a team to do more than one assignment in some divisions. This situation leads to the frequent clash of schedules. In this paper, an algorithm for scheduling system was developed to optimize the expatriate assignment. The methods used for developing the algorithms was vertex coloring of graph. This algorithm resulted in the optimal number of colors which is equivalent to the optimal time allocated for the expatriate assignment without any clash schedule among expatriates. The algorithm can be used for designing a software or application for scheduling system.

Keywords: scheduling system, vertex coloring, optimization, expatriate assignment

1. Introduction

Expatriation is carried out for the operational success of a company on an international scale [1]. In Indonesia, the existence of expatriates is aimed at advancing the quality of local workforce and human resources by transferring skills and transferring technology [2]. However, in practice, expatriates have strict regulations to maintain a balance between foreign workers and local workers [3]. Companies must be able to optimize the expatriate's limited workforce to complete several different tasks so that the results can be maximized. In this case expatriate scheduling has a limit on the amount while having more than one task in several divisions.

Some research on scheduling is carried out including scheduling in production that can determine the production schedule appropriately [4]. Order scheduling integrated with the company's order management process that can estimate when orders can be completed with diverse production process characteristics [5]. And Scheduling System for Plant Watering Using Electric Cars [6].

Various methods are tried to be applied in order to obtain optimal results and in accordance with existing conditions or constraints. The methods used for solving scheduling problems include the use of genetic algorithm methods in optimizing the scheduling through several stages, namely selection, crossover, and mutation [7]. Hybridization techniques in the bee colony algorithm (ABC) have also recently been tried to be applied to the timetabling problem to improve the many weaknesses that occur in the search process [8]. One of the methods considered to be able to produce a quick schedule solution is the application of Graph Coloring methods. This method is also widely used, by combining with other methods to continue the results of the coloring process because it is considered that this method still has a tendency for violations of soft constraints such as schedule results that exceed the quota of available space.
An example of a combination of methods in several studies using vertex coloring techniques in graphs is the implementation of Vertex graph coloring, particle swarm optimization and constraint-based reasoning, using the recursive largest first algorithm [9] and merging with the Simulated Annealing method in the sequel process [10]. Edge Coloring graph methods also used in scheduling problem of plant watering using electric cars and give the effective results for solving plants watering schedule problem and minimize the idle electric cars [11].

Course scheduling research using vertex graph coloring method has also been carried out with team teaching constraint that often leads to clash of the lecturers. In this case the results of the study were able to create algorithms that can provide solutions for all given degrees [12]. More applications of graph coloring for scheduling system can be seen, for example, in [13-16].

In this paper, aims to get an expatriate task scheduling solution with the constraints of the expatriate team having to do several tasks in several different divisions so there is no clash of schedule for each expatriate.

2. Methodology
This expatriate scheduling problem uses the vertex coloring graph method. The definition of graph is a collection of points and lines connecting some (possibly empty) subset of them. The points of a graph are most commonly known as graph vertices (vertex). Similarly, the lines connecting the vertices of a graph are most commonly known as graph edges [17]. It can be written as matrix $G = (V, E)$ where $V = \{v_1, v_2, v_3, \ldots\}$ as vertices of $G$ and a set $E = \{e_1, e_2, e_3, \ldots\}$ as edges of $G$ that represent the adjacencies between the vertices.

A vertex coloring is an assignment of labels or colors to each vertex of a graph such that no edge connects two identically colored vertices. The most common type of vertex coloring seeks to minimize the number of colors for a given graph [18].

The stages of the research carried out in this study go through several stages as illustrated in Figure 1.

![Figure 1. Stage of the research](image)

3. Result and Discussion
In this research, the number of color represent the schedule that can be run at the same time because it is certain that no team will clash. The different number of color means the schedule must be set in the different time, because any same expatariat in two or more task. Next, The algorithm to arrange the expatriate schedule is explained.

The first step to do is to determine the matrix ($MT$) that represents the relationship between each task where each task has its own expatriate team. The matrix will give a value of 1 if there are assignments with the same expatriate team member, if not given a value of 0. The relationship of this task is determined as a side in a graph. The number of sides owned by a vertex is called the degree ($\deg$).
The second step is to sort the degree values of matrix $MT$. This assignment matrix needs to be sorted from the highest degree to determine the vertex coloring first ($MSorted$). So, it will be colored from $M_{1...n}$. The Graph representation of the matrix can be shown in figure 2.

![Figure 2. Graph representation of Matrix $MSorted_{i,k}$](image)

The next step is the vertex coloring stage. The vertex with the highest degree will automatically be given the first color ($c_1$). Then, the next vertex with the next highest degree will be colored. Giving the next color is determined based on the rules of coloring the vertex on the graph that is from the next highest degree checked relations related to the points that have been colored before. If there is a relation then it should not use the same color, and vice versa. The checking process of the previous vertex that has been colored will produce a minimum number of colors according to the coloring theory of the graph. All results of color numbers can then be stored in a coloring matrix ($VColor_{i}$) to serve as an expatriate assignment schedule. The graph representation of Vertex Coloring ($VColor_{i}$) as seen in Figure 3. The same color number show that the assignment can be run at the same time because it is certain there are no equal teams. The assignment with the team member that collides will be plotted on the next schedule which is expressed through a different vertex color from the graph coloring result. In this Experiment, Assignment 1 and 2 can be run in the same time. But assignment 3 cannot be run with assignment 1 or 2. Here, just needed 5 schedules from 10 assignments and 8 maximum relation.
Figure 3. Graph representation of Vertex Coloring ($V_{\text{Color}}_i$)

$$V_{\text{Color}}_i = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{bmatrix} \quad \text{Schedule}_i = \begin{bmatrix} M1 & M2 \\ M3 & M6 \\ M4 & M5 & M10 \\ M7 & M9 \\ M8 \end{bmatrix}$$

From this result, the only data needed is a list of assignments for each division containing the names of the expatriate team members, with the assignment name being a vertex on the graph. The degree automatically can be generated from the process of calculating the number of relations between vertices. The results of this study can be used more generally not only for expatriate teams, but also for making schedules with single division cases (without teams).

4. Conclusion

From the discussion above, we can conclude that the expatriate scheduling problem can be solved using vertex graph coloring. The vertex represents the assignment for the expatriates and the edges represents the relation of each expatriate. This algorithm determines the optimal color for vertex coloring. The schedule is valid for scheduling the expatriate team and also for single expatriate. For further research, it can be developed with addition constraint such as limited time of schedule to finish the assignments.

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