Optimization of scheduling system for plant watering using electric cars in agro techno park

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Abstract. Agro Techno Park in University of Jember is a special area used for the development of agriculture, livestock and fishery. In this plantation, the process of watering the plants is according to the frequency of each plant needs. This research develops the optimization of plant watering scheduling system using edge coloring of graph. This research was conducted in 3 stages, namely, data collection phase, analysis phase, and system development stage. The collected data was analyzed and then converted into a graph by using bipartite adjacency matrix representation. The development phase is conducted to build a web-based watering schedule optimization system. The result of this research showed that the schedule system is optimal because it can maximize the use of all electric cars to water the plants and minimize the number of idle cars.

1. Introduction

Agro Techno Park in University of Jember is a special area used to develop agriculture, livestock and fisheries. Agro Techno Park area is about 14 hectares [1]. Processing and maintenance of plants in Agro Techno Park is still done manually, for example, in terms of plant watering schedule and plant management. The process of watering is done by the staff with a routine system and rely on instinct in the process of watering. Based on the interview, the plant watering is done twice a day. This leads to new problems because with less precise treatment resulted in the medicinal plants are not well developed. To handle these problems, Agro Techno Park University of Jember requires a technology that is able to perform watering automatically, can be controlled by scheduling system, and can be arranged according to the standard process. We assume the tools used here are electric cars as researched in University of Jember.

Methods often used to solve scheduling problems include graph coloring methods using edge coloring, or vertex coloring, or an addition with Artificial Intelligence. Welch-Powell algorithm is a graph coloring algorithm that performs staining based on the highest degree of its vertices or called Largest Degree Ordering (LDO) [2]. The algorithm can be used to color the edges of a graph efficiently. Another graph coloring algorithm was developed by Leighton using Recursive Largest First (RLF) [3].

The scheduling problem (university teaming) with more complicated variable also has been done. The specific case of lectures scheduling problem is a team teaching. One lecture is given by two or more teachers. The timetable is developed so that there is no clash of each two or more classes at the same time. The problem is solved by a vertex graph coloring [4]. The algorithm has also been developed into a website-based system [5]. More applications of graph coloring for scheduling system can be seen, for example, in [6,7,8,9].

The development of this automatic watering system begins with the development of the algorithm with the edge coloring graph technique. This technique can produce optimal number of colors as the option of watering schedule. The coloring result becomes the basis of the division of time on the watering schedule to avoid collisions on every itinerary. The smallest number of colors at each plant is chosen such that all the numbers result becomes the set of watering timetable. The algorithm is tested
randomly by giving data sets. This algorithm was designed in a common formula to be used both for the case scheduling watering plants with different frequencies and the different capacity of sprinklers cars [10]. This research develop watering scheduling system for Agro Techno Park using edge coloring of graph technique. This research was conducted in 3 stages: data collection phase, analysis phase and system development stage.

2. Data Collection Phase
At this stage, we collect data at Agro Techno Park in University of Jember. From the results of interviews conducted to one employee obtained data plants, data electric cars and employees. In the process of watering, it is done as much as 2 times a day. This treatment is carried out evenly to all existing plants although the frequency of watering each plant is different. Watering frequency and number of cars will be used as data parameters in determining the schedule of watering plants. The summary of collected data is presented in Table 1.

| Table 1. Number of plants and electric cars |
|-------------------------------------------|
| Number of plants                          | 57 |
| Number types of plants                    | 2  |
| number of plants with frequency of watering 1x | 36 |
| number of plants with frequency of watering 2x | 17 |
| number of plants with frequency of watering 3x | 4  |
| Number of electric cars                   | 3  |

3. Analysis Phase
In this experiment, we use three cars and five plants, both of which will be linked to each other according to the needs of the plant. Figure 1 shows a bipartite graph that represent the relationship between cars and plants. The edges indicates the certain cars can water the certain plants. The electric cars consist of three types, each of which is assumed to have certain access to each plant in accordance to the size of the car in order to reach the plant.

![Graph representation of the relationship between cars and plants](image)

**Figure 1.** Graph representation of the relationship between cars and plants

The car is represented using variable \( m \), while the plant is represented by variable \( n \). The frequency of the watering is represented using \( F[n] \). So the matrix representation of frequency and the degree as shown below. The adjacency matrix is represent as \( MT_{[d|m][n]} \). Using Welch Powell algorithm, the result of this experiment is matrix color \( C[m][n] \) and the graph representation as shown in Figure 2.
The next process by looking for the smallest coloring number of cars. The car with the smallest coloring number will serve to water the plants. This matrix is denoted by $TL[m]$. The results of the order of watering plants on the $TL[m]$ means that the car 1 to water the plant 1 and plant 7. At the same time the car 2 watering plant 3 and plant 6, and at the same time the car 3 watering plant 2, plant 4 and plant 5. This coloring process is repeat until the frequency of watering the plant is 0. This means the plant has been finished watered to the maximum frequency the plant may be watered. The graph representation are as shown in Figure 3.

4. System development stage
The development stage begins with describing the business process system. In this system, it also developed the management of data features of plants, electric cars and employees. The complete system features are shown in use case images as illustrated in Figure 4.
Figure 4. Business process system and Use Case diagram

Entity relationship diagram in this system presents the relationship between data in the database based on the basic objects of data that have interrelation relationship: plants, cars, user, watering. The entity relationship diagram is shown in Figure 5.

Figure 5. Entity relationship diagram

The scheduling page on this system can be accessed by the admin and users. In this page, data processing schedule watering can be done. This is the main feature of this system. The feature is presented the steps of making plant watering optimization schedule. The process starts from filling the adjacency table of the relationship between car and plant, line staining and watering sequence, and end up with the result of plant watering scheduling. The scheduling pages are illustrated in Figures 6.
Figure 6. User interface of plants watering scheduling system

The optimization process of plant water scheduling system implements edge coloring of graph technique. Edge coloring techniques on the graph are used to illustrate the relationship between plants and electric cars. This relationship explains which electric car can water which plants. From this relationship, the optimal number of color will find through the edge coloring of graph technique. While adjacency matrix is used to convert the relationships on the graph, so that it becomes a table that produces the order of watering the plants. The relationship between the graph coloring and the adjacency matrix will provide optimal plant watering solutions.

Dashboard page with all the features of this system can be accessed by admin. These features are user data, car data, plants data and watering. The scheduling page on this system can be accessed by the admin and user. On this page, we can process data watering schedule. This feature presents the steps of making plant watering optimization schedule. The process starts from filling the adjacency table of the relationship between cars and plants, edge coloring and watering sequence which is the result of plant watering scheduling. The input data is sorted according to the highest degree then colored by representing the numbers and matrix adjacency. The next page contains the scheduling data stored in the database. On this page, it can be seen the detail of the watering process as a result of calculations that have been done. Then the scheduling detail page of the plant watering scheduling process contains the final calculation results of plant watering scheduling. This page contains a table showing which cars water which plants. With this calculation, the schedule of plant watering by electric car is optimised. In other words, this scheduling system can maximize the use of all electric cars to water the plants and minimize the number of idle cars.

5. Conclusion

From the discussion above, we can conclude that: (1) graph coloring is used to color the edge (relationship for watering) between plants with electric cars which is used the Welch Powell algorithm to determine the optimal color for edge coloring; (2) After coloring all edges, then the graph was represented into the matrix adjacency table; (3) the system of plant watering schedule is developed to optimize the watering schedule of plants in the Agro Technopark University of Jember; (4) the schedule is valid for daily schedule provided there is no addition of electric cars and plants; and (5) the acquisition of scheduling results depends on the plants, electric cars and the intensity of watering from each plant.
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