



Application of the Welch-Powell Algorithm on Graph Coloring in Mapping Village Area in Alor Island, East Nusa Tenggara

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Abstract

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This study aims to introduce the concept of graph coloring using the Welch – Powell algorithm in an effort to help related parties, in this case the government in the Alor Island region, to facilitate the coloring of village maps. The method used in this research is descriptive quantitative research method which aims to explain a phenomenon by using numbers that describe the characteristics of the subject under study. The results of graph coloring made in this study produce at least 5 colors needed to color the map. The number of vertices (villages) on the Alor Island map is 120, and the chromatic number in the graph of the Village map on Alor Island is 5 ($\chi(G) = 5$). The vertices (villages on Alor Island) can be colored using only five colors, and between Villages that border each other have different colors.

Keywords: Graph Coloring, Welch-Powel Algorithm, Villages Maps, Alor Island.

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INTRODUCTION

Graph theory was first introduced by Leonard Euler in 1736 when he thought about whether or not it was possible to cross all the bridges in the city of Königsberg–Russia only by crossing them once, and starting and ending at the same place. The solution he proposed to the problem was in the form of points and edges which became known as graph theory. Since then, the topic of this graph has been studied by mathematicians (De, 2022).

A graph G is a pair $(V(G), E(G))$, where $V(G)$ is a finite nonempty set called the vertex-set of G and $E(G)$ is a set of unordered pairs $\{u, v\}$ (or simply uv) of distinct elements from $V(G)$ called the edge-set of G . The elements of $V(G)$ are called vertices and the cardinality $|V(G)|$ of $V(G)$ is the order of G . The elements of $E(G)$ are called edges and the cardinality $|E(G)|$ of $E(G)$ is the size of G (Enriquez, 2016).

Graph coloring is an important problem with its wide variety of applications. This topic has a very interesting history and its theories have caused much debate among mathematicians (Donderia and Jana, 2012). Graph coloring is a classic problem within the field of structural and algorithmic graph theory that has been widely studied in many variants (Lima, van Leeuwen and van der Wegen, 2021). Kocay divides graph coloring into three types, one of which is vertex coloring. Vertex coloring is coloring the vertices of a graph such that no two neighboring vertices have the same color. The purpose of doing a graph coloring is not only limited to coloring the vertices so that the vertices that are next to each other do not have the same color, but more than that to keep the number of colors used to color a graph to a minimum. The minimum number of colors that can be used to



color a graph is called the chromatic number of the graph $G(\chi(G))$ (Ammar, 2019). Or symbolically, Let $G = (V, E)$ be a simple graph with finite vertex set. For $k \in \mathbb{N}$, a map $\alpha: V \rightarrow \{1, 2, \dots, k\}$ is called a k -coloring of G , and $\alpha(v)$ is called the color of v . If $\alpha(u) \neq \alpha(v)$ for all $uv \in E$, α is a proper k -coloring of G (Beier *et al.*, 2016).

One important application of the graph coloring problem is coloring the map of an area, for example coloring the Village area in a district. In the coloring process, sometimes it is done without taking into account the minimum number of colors that can be used, but focuses more on the color dissimilarity of two adjacent Villages. This can result in the use of a number of colors that are wasteful and indirectly have an impact on the problem of increasing costs, time and effort. These problems can be solved by applying the concept of graph coloring, especially vertex coloring. Besides being able to color the map easily, this concept can also calculate the minimum number of colors that can be used to color the map.

Based on the results of initial interviews with several map coloring actors from several villages and districts, this problem is also felt by the general public, especially people in Alor Regency because the concept of graph coloring has never been applied in the Alor Regency area, especially the application of the concept of graph coloring in coloring a map. However, some people have thought and found a solution to the problem, but they did not realize that the result of the thought was the concept of graph coloring or that the coloring did not follow a systematic procedure in accordance with the concept of graph coloring.

There are several algorithms that can be used in graph coloring, one of which is the Welch – Powell algorithm. The Welch – Powell algorithm is used to color a graph, by sorting all vertices based on their degrees from the largest degree to the smallest degree, then taking the first color (eg red), coloring the first vertex that we have sorted by degree earlier. Then color the following non-neighborhood points with the same color (red) then continue with the second color, and so on until all the vertices have been colored (Maro and Purab, 2021).

Many studies have been carried out on the problem of graph coloring, but its development in the Alor Regency area has not been widely studied, especially in map coloring in the Alor Regency area. The studies that have been carried out include “Genetic Algorithm Analysis using the Graph Coloring Method for Solving the University Timetable Problem” (Assi, Halawi and Haraty, 2018), “Implementation of Graph Coloring Using Welch-Powell Algorithm to Determine Student Mentoring Schedule” (Bustan and Salim, 2019), “Distributed Minimum Vertex Coloring and Maximum Independent Set in Chordal Graphs” (Konrad and Zamaraev, 2022), “Application of Graph Coloring in Making Semester Exam Schedules at the Department of Mathematics Education, Islamic University of Jember” (Mahmudah and Irawati, 2018), “Implementation of Graph Coloring Using The Welch – Powell Algorithm for Course Scheduling” (Puteri, 2017), “Application of Graph Coloring Concepts in Compiling Class Schedules Using the Welch-Powell Algorithm Method in Programs Informatics Engineering Studies, Faculty of Mathematics and Natural Sciences, Tribuana University of Kalabahi” (Maro and Purab, 2021), “Graph Coloring Applications for Optimizing Traffic Light Settings in Sukoharjo” (Meiliana and Maryono, 2017), “Graph

Coloring on The Map Using a Greedy Algorithm (Case Study : DKI Jakarta Provincial Map)" (Irsal, 2017), "Application of Welch-Powell Algorithm in Graph Coloring In Regional Mapping in Medan City" (Lestari and Mulyono, 2020), and "Data Reduction for Graph Coloring Problems" (Jansen and Kratsch, 2013).

Based on the description of the problem, this study aims to introduce the concept of graph coloring using the Welch-Powell algorithm in an effort to help related parties, in this case the government in the Alor Regency area, to facilitate the coloring of Village maps. This research was only conducted to color the map of the Village area in the Alor Island region considering that the Alor Regency area consists of two large islands, namely Alor Island and Pantar Island, as well as several small islands around it.

METHODS

The method used in this research is descriptive quantitative research method. Descriptive quantitative research is research that has the aim of describing a phenomenon, events, symptoms, and events that occur factually, systematically, and accurately. Phenomena can be in the form of forms, activities, relationships, characteristics, as well as similarities and differences between phenomena. Descriptive quantitative research method aims to explain a phenomenon by using numbers that describe the characteristics of the subject under study.

The techniques that will be carried out in this research are described in the following steps: draw a map of the village area on Alor Island along with the boundaries of each village area; determining the neighbourhood between villages in Alor island where two villages are said to be neighbors if they are directly adjacent to each other; representing a map of the Village area in the form of a graph taking into account the neighbours; determine the coloring of each village using the Welch – Powell algorithm; determine the chromatic number of the graph; make a solution to the problem in the form of a map of the Village area using the Welch – Powell algorithm and the chromatic number obtained.

RESULTS & DISCUSSION

In this study, the object raised is the village area located on Alor Island, Alor Regency, East Nusa Tenggara Province and by implementing the concept of graph coloring of a map using the Welch-Powell algorithm, where each village is represented in the form of a vertice and the direct boundary of the area between villages is represented in the form of an edge.

As for doing graph coloring using the Welch-Powell Algorithm using the following steps: collecting data or information in the form of a map of the village area on Alor Island and its territorial boundaries obtained using Google maps and Google Earth; representing a map of the Village area on Alor Island in the form of a graph with the Village area in the form of a vertice and the area that is directly adjacent to it is connected by an edge; then use the Welch – Powell Algorithm to do the coloring.

Figure 1 is a map of the village area on Alor Island, Alor Regency, East Nusa Tenggara Province.



Figure 1. Map of Village/Urban Areas on Alor Island

In Figure 1, it is known that the Alor Island map consists of 120 villages which are represented as a graph by representing the Village area as a node and the Villages that are directly adjacent to it are represented by sides. Each village area is named 1, 2, 3, 4, 5, ..., 120. The following figure 2 is the result of the representation of the map of the village area on Alor Island in graph form.

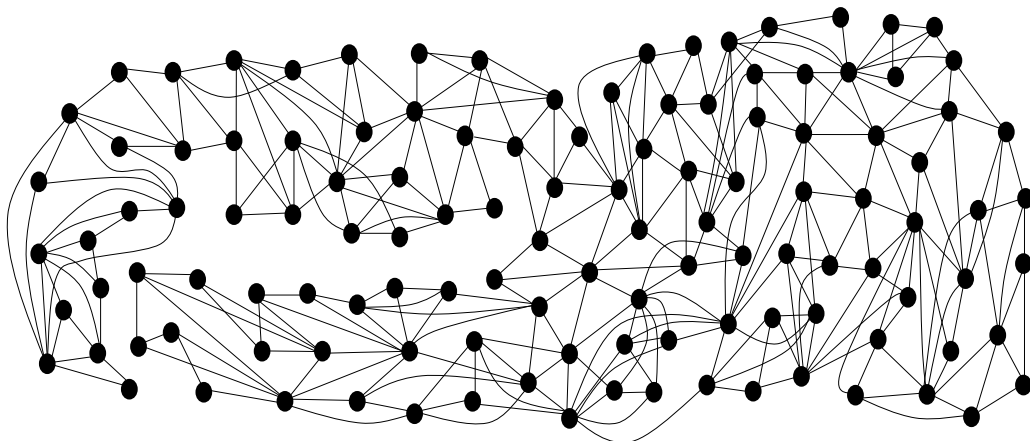


Figure 2. Graph of Village Area Map on Alor Island

Then the graph in Figure 2 is colored using the Welch-Powell algorithm and obtains the coloring results as shown in Figure 3.

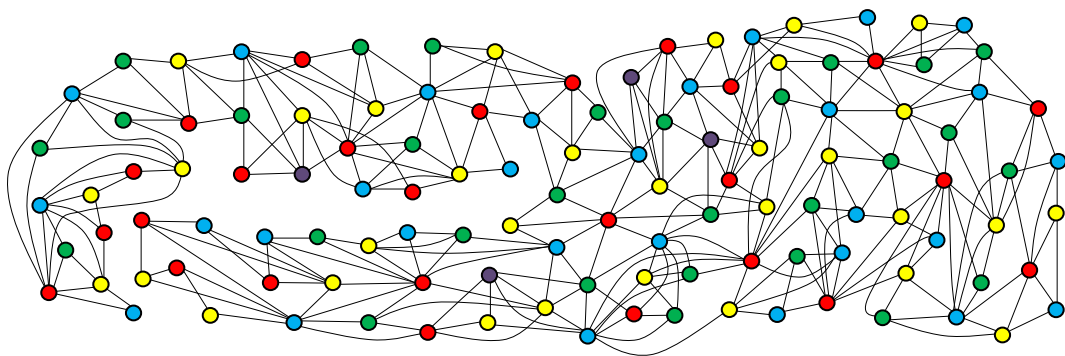


Figure 3. Graph coloring results using the Welch-Powell algorithm

With the end of the coloring process for the vertices of the graph to the fifth color and all the vertices have been colored, then the coloring of the vertices of the graph from the map representation of the Village area on Alor Island has been completed. Thus, it can be said that the concept of graph coloring using the Welch-Powell algorithm can be applied to color the map of the Village area on Alor Island. The color optimization that has been successfully carried out in coloring the Village area map on Alor Island, Alor Regency is 5 colors, or the chromatic number obtained is 5 ($\chi(G) = 5$).

Based on Figure 3, a map of the Village area on Alor Island can be made along with the coloring of each area as shown in Figure 4.

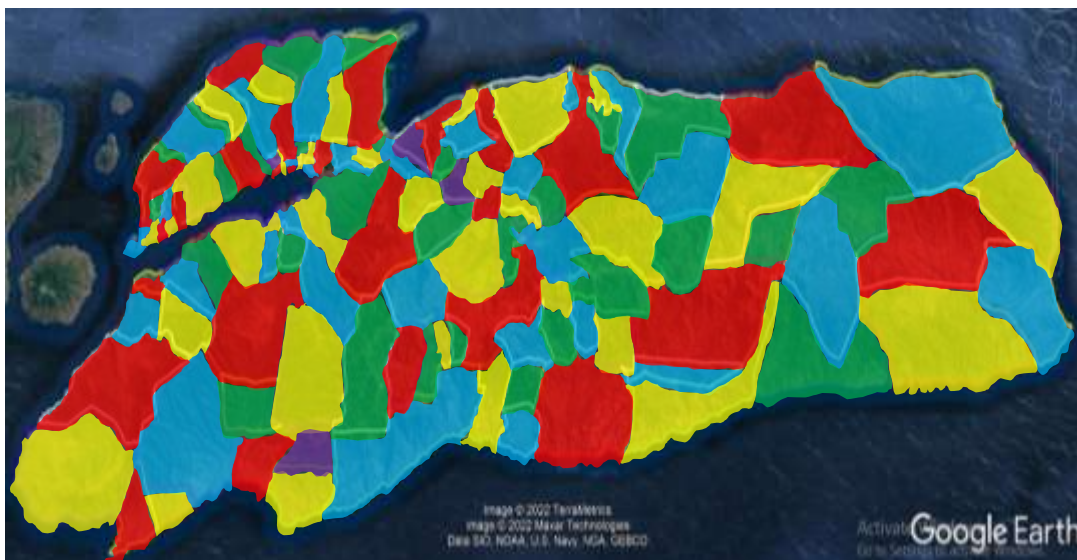


Figure 4. Map of Village Areas on Alor Island and Coloring of Each Area

CONCLUSION

Graph coloring using the modified Welch-Powell Algorithm can be used to solve the problem of graph coloring on the Village/Kelurahan area map on Alor Island to make it easier to map each area on Alor Island. The results of graph coloring made in this study produce at least 5 colors needed to color the map. The number of vertices (villages) on the Alor Island map is 120, and the chromatic number in the graph of the Village map on Alor Island is 5 ($\chi(G) = 5$), the vertices (villages on Alor Island) can be colored using only five colors, and between Villages that border each other have different colors.

Suggestions that can be submitted to further researchers based on this research is to apply the concept of graph coloring for coloring the map of the Village area on Alor Island, but by using another type of algorithm. In addition, further research can also be developed for village coloring on Alor Island, but it is carried out for each district.

CONFLICT OF INTEREST

This paper doesn't have a potential conflict of interest because the paper describes the use of the concept of graph coloring in coloring villages map and collecting village boundary data obtained from google maps and google earth.

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