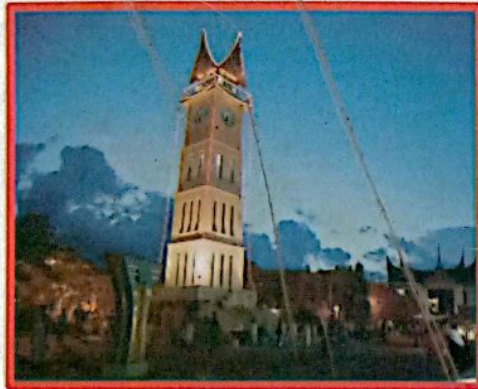


**The 5<sup>th</sup> IMT - GT  
International Conference  
on Mathematics, Statistics  
and Their Applications  
ICMSA 2009**

**Editors :**  
**I Made Arnawa, Muhafzan,  
Maiyastri, Susila Bahri**



**June 9-11, 2009  
The Hills Hotel  
Bukittinggi, Indonesia**

Organized by :



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**(ICMSA 2009)**

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June 2009



# Preface

First of all, I would like to say welcome to Bukittinggi, Indonesia to all of you. It is an honour for us to host this conference. We are very happy and proud because the participants of this conference come from many countries; we have participants from Libya, Japan, Qatar, India, Malaysia, Singapore, Thailand, Iran, and many more.

Ladies and gentlemen, according to constructivism theory, mathematics comes out as a result of social construction; that's why, the outcomes of our researches in mathematics, like theorem or formula of mathematics, should be communicated in a scientific forum such as seminar or conference. Through this kind of seminar or conference, we could refine the existing theorems or we could get new ideas to produce a new one. Seminar or conference which is held annually enables us to continually develop the science of mathematics until the end of the time.

That's way, in this two-day conference, we are going to discuss around 250 papers coming from diverse aspects of mathematics ranging from analysis, applied mathematics, statistics, algebra, Computational Mathematics, mathematics education, and other related topics.

For all of us here, I would like to convey my endless appreciation and gratitude for your participation in this conference.

Thank you very much



**Dr. I Made Arnawa**  
*Chairman of the Conference*

## Message from Rector Andalas University

It gives me great pleasure to extend my sincere and warm welcome to the participants of the 5th International Conference on Mathematics Statistics and Application (The IMT GT's 5th ICMSA 2009) - A Joint Scientific Program organized by Universities over Indonesia, Malaysia and Thailand Growth Triangle Region. On behalf of Andalas University, let me welcome all of you to the conference in Bukittinggi, West Sumatra Province, the land of Minang kabau.

We believe that from this scientific meeting, all of participants will have time to discuss and exchange ideas, findings, creating new networking as well as strengthen the existing collaboration in the respective fields of expertise. In the century in which the information is spreading in a tremendous speed and globalization is a trend, Andalas University must prepare for the tough competition that lay a head. One way to succeed is by initiating and developing collaborative work with many partners from all over the world. Through the collaboration in this conference we can improve the quality of our researches as well as teaching and learning process in mathematics and to achieve standards and requirements applied in many developed countries. I strongly believe that this conference is and extraordinary testimony to our capacity building at international, regional and local level.

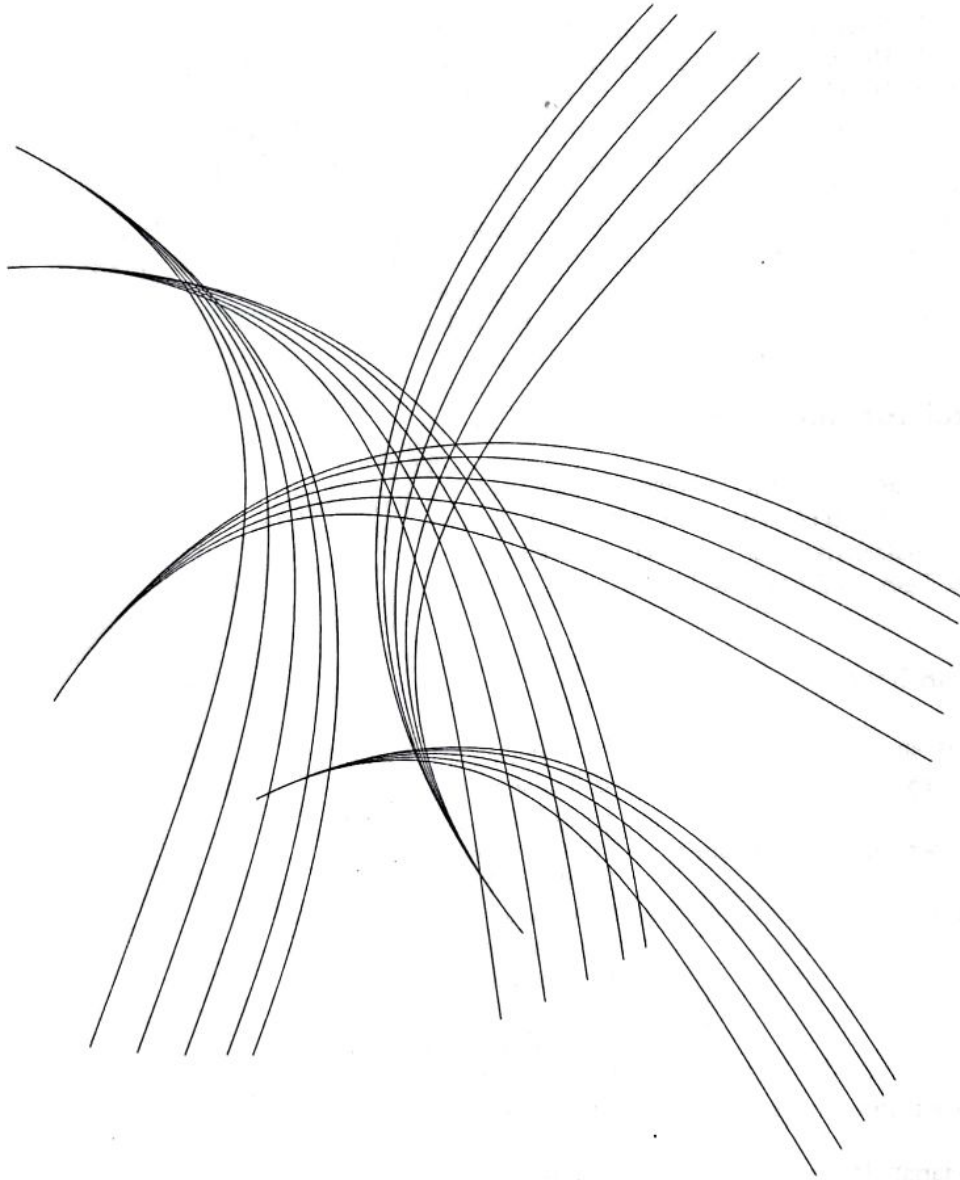
I would like to express my deep gratitude to International Scientific Committee of who has honored the Mathematics Department, Faculty of Mathematics and Natural Sciences, Andalas University to host this prestigious conference. This is a very special opportunity for us to be involved in a regional community of knowledgeable scientist in the field of mathematics, statistics and their applications. I would also like to extend my gratitude to keynote speakers, participants, and organizer of this conference for their contribution to this event. My special thank is also rendered to the local government of West Sumatra for various supports and facilities.

Finally I wish all participants a fruitful deliberation at the conference. I also wish all participants and accompanying spouses a pleasant and enjoyable stay in Bukittinggi City, West Sumatra.



**Prof. Dr. Ir. Musliar Kasim, MS**  
*Rector*

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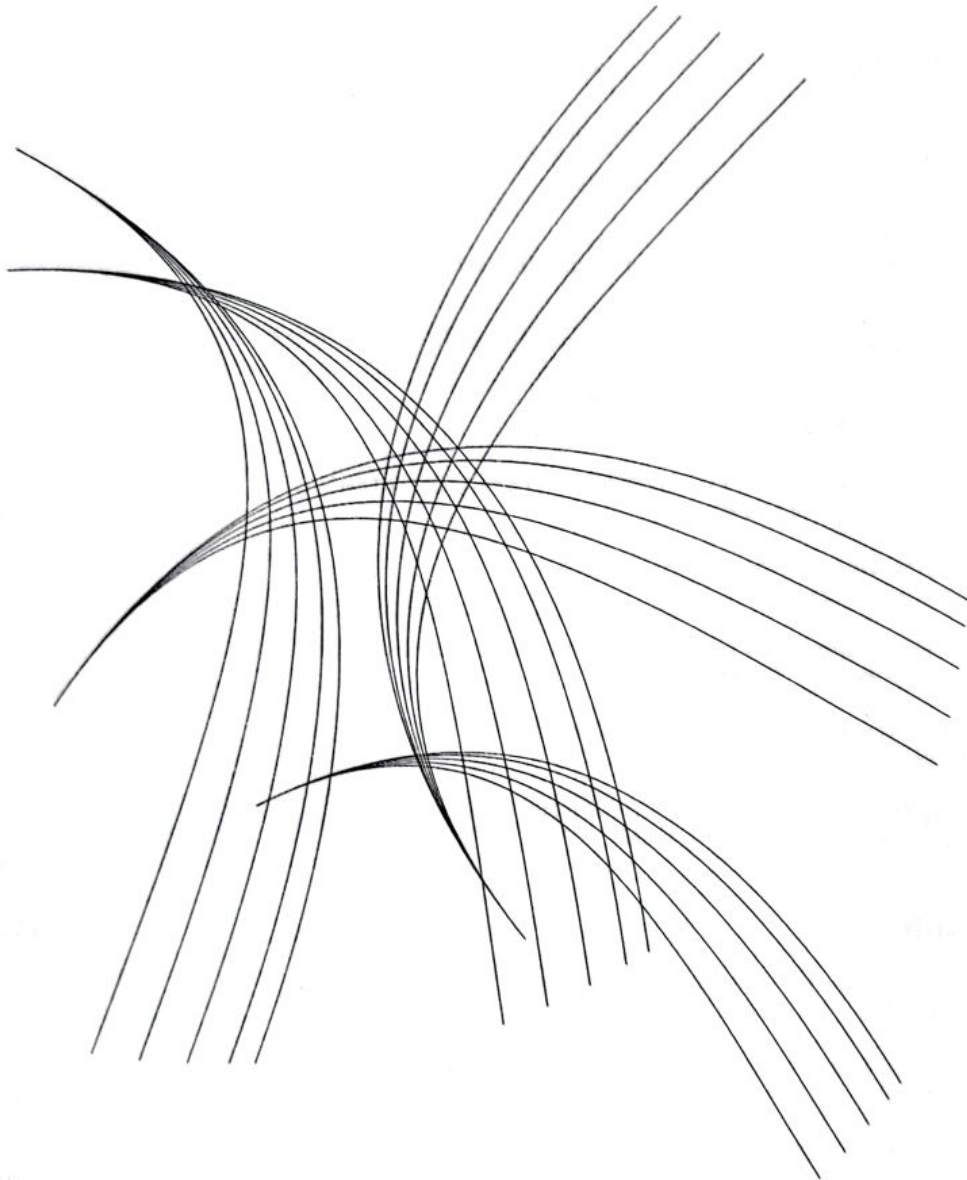
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## Arranging The Examination Schedule By Using Graph Coloring Algorithm

<sup>1</sup>Budi Rahmadya, <sup>2</sup>Narwen

Department of Mathematics, Faculty of Mathematics and Natural Science,  
Andalas University, Padang, Indonesia  
E-mail : Budi22\_ok@yahoo.com, Narwen@fmipa.unand.ac.id

### Abstract

One of the applications related to graph is the graph coloring. Graph coloring consist of vertices, edges and domain coloring. In this writing, the writer specifically discusses the vertices coloring. The vertices coloring is the application of colors to the vertices of a graph in such a way so that there are no adjacent vertices have similar color. This method can be implemented in arranging the examination schedule, and then the minimum time in conducting examination can be achieved.

**Keywords :** graph, graph coloring, vertices coloring, vertices, edge.

### 1. Introduction

The proportional schedule setting plays a significant role in the smooth operation of the institution and organization activities. A proportional schedule should consider all aspects affecting the schedule. The difference of aspects affecting the schedule may affect the result of the schedule.

The problems in arranging the examination Schedule that needs to be solved may affect the creation of an examination Schedule, such as: the limitation of time, and the students who takes different subjects in different semester. Sometimes, in one shift of examination, there is only one examination Schedule taking place, thus in a semester with many allocation of subjects may take a long examination time to finish.

In mathematics perspective, the arrangement of examination Schedule can be tackled by using the graph coloring algorithm, so an effective examination Schedule can be produced and it assures there will no students who takes two or more subjects have examination Schedule in the same time. Based on this algorithm, a simple application program can be made by processing the data input of the examination Schedule, the students taking the subjects, and in the ends it results the intended proportional Schedule.

The objective of this thesis is to arrange an examination schedule and suggests the steps involved in arranging the examination schedule by using the vertices coloring algorithm in graph and the steps of vertices coloring by using the pascal programming language, which then can be applied in Borland Delphi 7.

### 2. The Background of the Theory

The graph theory has been an old theory but has many implementations until today. Graph is used to present the described objects and their relation among those objects. The visual representation of a graph is by stating objects with a dot or vertices, while the relation among objects is stated in the forms of lines or edge.

Graph  $G = (V, E)$  consists of the finite compilation of dots or vertices (vertices)  $V = \{v_1, v_2, \dots\}$  with  $V \neq \emptyset$ , is noted as  $V(G)$  and finite compilation edges  $E = \{e_{11}, e_{12}, \dots, e_{ij}, \dots\}$ , is noted as  $E(G)$ . The edge  $e_{ij}$  is identified as the compilation of a series of pair of vertices  $(v_i, v_j)$ . The vertex of  $v_i$  and vertex of  $v_j$  in a mutual accord with the edge  $e_{ij}$  are called the tip points of  $e_{ij}$ . Loop is the edge of vertices with the same tip points. The finite graph is a graph with the finite compilation of vertices.

The simple graph is a graph with the absence of loop and parallel edges. For example  $v$  is a vertex, and  $e$  is an edge of a graph. If  $e = vv_0$  with  $v_0$  as other vertex of the graph, then vertex  $v$  is called incidental to the edge  $e$ , and the edge  $e$  is called incidental with vertex  $v$ .

Two vertices  $v_i$  and  $v_j$  in graph  $G$  is called adjacent if and only if the two vertices from the same edges, which are  $e_{ij}$  or  $v_i v_j \in E$ . The vertices degree of  $v_i$  in graph  $G$ , noted as  $d(v_i)$  is the number of related edges with  $v_i$ , or the number of vertices that is adjacent with  $v_i$ . Then the degree of loop is counted twice.

The  $G$  is stated as connected graph if each of the two vertices in  $G$  graph has the connected trajectory. The Adjacency Matrices [7], for example  $G = (V, E)$  is a graph with vertex  $m$ , for example:

$$v_1, v_2, \dots, v_m. \text{ Then the adjacency for this graph is in the form :}$$

$$\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mm} \end{pmatrix}$$

Where the element  $a_{ij}$  in line  $-i$  and column  $-j$  have the value of 1 if the vertices  $-i$  is adjacent with vertices  $-j$ , with the value 0 for others.

For all the adjacency matrices of the simple graph is the symmetrical matrices or  $a_{ij} = a_{ji}$ , for every  $i$  and  $j$ , where  $a_{ij}$  symbolize the element of line  $-i$  and column  $-j$ .

The definition of graph coloring according to [3] is the application of colors which are usually represented as series of numbers starting from 1, in a certain object of a graph. The objects may appear in the form of dots, edges, domain or the combination of those three.

The colouring problem can be described in graph  $G$  with  $n$  vertices ready to be colored, where there are no two adjacent vertices have a same color. Then, the vertices with the same color are grouped in one compilation, called partitioning problem. Classification can be done to the vertices or the edges of a graph.

The coloring of a simple graph  $G$  is the application of every vertices in  $G$  where there are no adjacent vertices have the same colors. The number of the smallest color is needed to color the graph so that there are no two adjacent vertices the same colors and it is called chromatic number of the graph, symbolized as  $\chi(G)$ .

In this writing, the writer only discusses the problem of scheduling, so the topic discussed further is only about the vertices coloring.

#### The Guidelines of Vertices Coloring in Graph are :

For example the graph  $G = (V, E)$  is a graph with  $n$  vertices which is  $v_1, v_2, \dots, v_n$ . Then the steps in the vertices coloring of a graph are :

1. Organize vertices  $v_1, v_2, \dots, v_n$  from the highest degree to the lowest degree. For example the organization of vertices obtained from the highest degree to the lowest degree is  $v_1', v_2', \dots, v_n'$ .
2. Start from the vertices with the highest degree, for example vertex  $v_1'$ . Apply any color to the vertex  $v_1'$ , for example color 1.
3. The application of the color to the vertex  $v_2'$  is done in a way if vertex  $v_2'$  is connected with vertex  $v_1'$ , then apply different color to  $v_2'$  from the color of vertex  $v_1'$ .
4. For  $i = 3, 4, \dots, n$ , apply the coloring of vertex  $v_i'$ , by comparing the vertex  $v_i'$  with all the colored vertices. If vertices  $v_i'$  is connected to vertices  $v_n'$ , then the color applied to the vertices should be different from the color of vertex  $v_n'$ .
5. The coloring of vertices in graph can be done by using the adjacency matrices. Based on the adjacency matrices, the graph coloring can be implemented with the guidelines as follows:
  - a. If  $a_{ij} = 1$  or vertices is connected with vertices  $v_j$ , then the color of vertex should be different from the color of vertex  $v_j$
  - b. If  $a_{ij} = 0$  or vertex  $v_i$  is not connected to the vertex  $v_j$ , then the color of vertex  $v_i$  can be similar to the color of vertex  $v_j$

### 3. The Arrangement of Examination Schedule

In the mathematics department of Mathematics and science Faculty of Universitas Andalas, for the academic year of 2008/2009 there 45 required subjects and 15 optional subjects, listed as follows :  
The Required Subjects :



$$A = \begin{pmatrix} 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 \end{pmatrix}$$

The degree of each vertices is obtained from the number of other vertices that are connected to those vertices or by calculating the edges element or the column of adjacency matrices, with the result as follows :

Verteks	Derajat	Verteks	Derajat
1	12	12	15
2	12	13	15
3	19	14	17
4	12	15	17
5	5	16	17
6	5	17	15
7	19	18	13
8	17	19	15
9	10	20	15
10	17	21	8
11	15	22	8

Based on the guidellines and sampling above, an adjacency matrices can be made with the series matrices that are organized from the highest degree to the lowest degreewith the dimension of 22 x 22 , as shown follows :

$$V_3 \begin{pmatrix} V_3 & V_7 & V_8 & V_{10} & V_{14} & V_{15} & V_{16} & V_{11} & V_{12} & V_{13} & V_{17} & V_{19} & V_{20} & V_{18} & V_1 & V_2 & V_4 & V_5 & V_{21} & V_{22} & V_3 & V_6 \\ V_7 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ V_8 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ V_{10} & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ V_{14} & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ V_{15} & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ V_{16} & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ V_{11} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ V_{12} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ V_{13} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ V_{17} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ V_{19} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ V_{20} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ V_{18} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ V_1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 1 \\ V_2 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ V_4 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \\ V_5 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ V_{21} & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ V_{22} & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ V_3 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \\ V_6 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}$$



Based on the adjacency matrices stated above, the coloring of the vertices can be implemented as follows :

follows :

1. For example  $v_3$  is colored with the color no. 1.
2. The vertices  $v_7$  is connected with vertices  $v_3$ , then the coloring of vertices  $v_7$  can not be in the similar color to the vertex  $v_3$ . For example, the vertex  $v_7$  is colored with the color no. 2.
3. The vertex  $v_8$  is connected with vertices  $v_3$  and  $v_7$ , then the color of vertex  $v_8$  can not be similar with the color of the vertex  $v_3$  and  $v_7$ . For example, the vertex  $v_8$  is colored with the color no. 3.
4. The vertex  $v_{10}$  is connected with the vertices  $v_3$ ,  $v_7$  and  $v_8$ , then the color of vertices  $v_{10}$  can not be similar to the color of vertex  $v_3$ ,  $v_7$  and  $v_8$ . For example, the vertex  $v_{10}$  is colored with the color no. 4.
5. The vertex  $v_{14}$  is connected with the vertices  $v_3$ ,  $v_7$ ,  $v_8$  and  $v_{10}$ , then the color of vertex  $v_{14}$  can not be in similar color with vertices  $v_3$ ,  $v_7$ ,  $v_8$  and  $v_{10}$ . For example, the vertex  $v_{14}$  is colored with the color no. 5.
6. The vertex  $v_{15}$  is connected with vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$  and  $v_{14}$ , then the color of vertex  $v_{15}$  can not be in similar color with the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$  and  $v_{14}$ . For example vertex  $v_{15}$  is colored with color no.6.
7. The vertex  $v_{16}$  is connected with vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$  and  $v_{15}$ , then the color of vertex  $v_{16}$  can not be similar to the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$  and  $v_{15}$ . For example, vertex  $v_{16}$  is colored with color no. 7.
8. The vertex  $v_{11}$  is connected to the vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$  and  $v_{16}$ , then the coloring of vertex  $v_{11}$  can not be similar with the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$  and  $v_{16}$ . For example vertex  $v_{11}$  is colored with color no. 8.
9. The vertex  $v_{12}$  is connected with vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$  and  $v_{11}$ , then the color of vertex  $v_{12}$  cannot be similar to the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$  and  $v_{11}$ . For example, vertex  $v_{12}$  is colored with color no. 9.
10. The vertex  $v_{13}$  is connected with vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$  and  $v_{12}$ , then the color of vertex  $v_{13}$  cannot be similar to the that of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$  and  $v_{12}$ . For example, vertex  $v_{13}$  is colored with color no. 10.
11. The vertex  $v_{17}$  is connected with the vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$  and  $v_{13}$ , then the color of vertex cannot be in the similar color to the vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$  and  $v_{13}$  , so vertex  $v_{17}$  is colored with color no. 11.
12. The vertex  $v_{19}$  is connected to the vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$ ,  $v_{13}$  and  $v_{17}$ , then the color of the vertices  $v_3$  can not be in the similar color with that of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$ ,  $v_{13}$  and  $v_{17}$ . For example, vertex  $v_{19}$  is colored with color no. 12.
13. The vertex  $v_{20}$  is connected with vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$ ,  $v_{13}$ ,  $v_{17}$  and  $v_{19}$ , then the color of vertices  $v_{20}$  cannot be in the similar color to that of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$ ,  $v_{13}$ ,  $v_{17}$  and  $v_{19}$ . For example, vertex  $v_{20}$  is colored with color no. 13.
14. The vertex  $v_{18}$  is connected with vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$ ,  $v_{13}$ ,  $v_{17}$ ,  $v_{19}$  and  $v_{20}$ , then the color of vertex  $v_{18}$  cannot be similar to the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ ,  $v_{16}$ ,  $v_{11}$ ,  $v_{12}$ ,  $v_{13}$ ,  $v_{17}$ ,  $v_{19}$  and  $v_{20}$ . For example, the color of vertex  $v_{18}$  is colored with color no 14.
15. The vertex  $v_1$  is connected to the vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ . Then the color of vertex  $v_1$  cannot be in similar color to that of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ , but vertex  $v_1$  is not connected to vertex  $v_{11}$  so vertex  $v_1$  is colored with the same color with the color of vertex  $v_{11}$  which is the color no. 8.
16. The vertex  $v_2$  is connected to the vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ , then the color of vertex  $v_2$  cannot be similar to the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ . Vertex  $v_2$  is not connected to vertex  $v_{11}$ , because vertex  $v_{11}$  has the similar color to the color of vertex  $v_1$  and vertex  $v_1$  is connected to vertex  $v_2$ , then the color of vertex  $v_2$  cannot be in similar color to the color of vertex  $v_1$ . Vertex  $v_2$  is not connected to vertex  $v_{12}$ , then the color of vertex can be similar to the color of vertex  $v_{12}$ , which is color no. 9.
17. The vertex  $v_4$  is connected to vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ , then the color of vertex  $v_4$  cannot be similar with the color of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ . Vertex  $v_4$  is not connected to vertex  $v_{11}$ , because vertex  $v_{11}$  has similar color to the color of vertex  $v_1$  and vertex  $v_1$  is connected to vertex  $v_4$ , so the color of vertex  $v_4$  cannot be the same with the color of vertex  $v_{11}$ . The vertex of  $v_4$  is not connected to vertex  $v_{12}$ , because vertex  $v_{12}$  is in the similar color with vertex  $v_2$  and vertex  $v_2$  is connected to vertex  $v_4$ , then the color of vertex  $v_4$  cannot be in similar color with the color of vertex  $v_{12}$ . Vertex  $v_4$  is not connected to vertex  $v_{17}$  then the color of vertex  $v_4$  can be in similar color with the color of vertex  $v_{17}$ , which is the color no. 10.
18. The vertex  $v_9$  is connected to vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ , then the color of vertex  $v_9$  can not be similar to that of vertices  $v_3$ ,  $v_7$ ,  $v_8$ ,  $v_{10}$ ,  $v_{14}$ ,  $v_{15}$ , and  $v_{16}$ . Vertex  $v_9$  is not connected to vertex  $v_{11}$ , because vertex  $v_{11}$  has a similar color with the color of  $v_1$  and vertex  $v_1$  is connected with vertex  $v_9$ , then the color of vertex  $v_9$  can not be in similar color to vertex  $v_1$ . Vertex  $v_9$  is not connected to vertex  $v_{12}$ , but, because vertex  $v_{12}$  has similar color to the color of vertex  $v_2$  and vertex  $v_2$  is connected to vertex  $v_9$ , then the color of vertex  $v_9$  cannot be in similar color to the color of vertex  $v_{12}$ . Vertex  $v_9$  is not connected to vertex  $v_{13}$ . Because vertex  $v_{13}$  has similar color to the color of vertex  $v_3$  and vertex  $v_3$  is connected to vertex  $v_9$ , then the color of vertex  $v_9$  cannot be similar to the color of vertex  $v_{13}$ . Vertex  $v_9$  is not connected to vertex  $v_{17}$ , because vertex  $v_{17}$  has similar color with vertex  $v_4$  and vertex  $v_4$  is connected with  $v_9$  then the color of vertex  $v_9$  cannot be in similar color with that of verice  $v_{17}$ . Vertex  $v_9$  is not connected to vertex  $v_{19}$  , so vertex is in the color no. 11.



19. The vertex  $v_{21}$  is not connected to vertex  $v_3$ , then the color of vertex  $v_{21}$  can have similar color to vertex  $v_3$  so vertex  $v_{21}$  has color no. 1.
20. The vertex  $v_{22}$  is not connected to vertex  $v_3$ , because vertex  $v_3$  has similar color to vertex  $v_{21}$  and vertex  $v_{21}$  is connected to vertex  $v_{22}$ , then the color of vertex  $v_{22}$  cannot be similar to the color of vertex  $v_3$ . Vertex  $v_{22}$  is not connected to vertex  $v_8$ , then the color of vertex  $v_{22}$  can have the same color with vertex  $v_8$ , so the color of vertex  $v_{22}$  is color no.3.
21. The vertex  $v_5$  is connected to vertex  $v_3$ , so the color of vertex  $v_5$  cannot be the same with the color of vertex  $v_3$ . Vertex  $v_5$  is not connected to vertex  $v_7$ , then the color of vertex  $v_5$  can be similar to the color of vertex  $v_8$ , and the color is color no.2.
22. The vertex  $v_6$  is connected to vertex  $v_3$ , so the color of vertex  $v_6$  cannot be similar to the color of vertex  $v_3$ . Vertex  $v_6$  is not connected to vertex  $v_7$ . Since vertex  $v_7$  has similar color to vertex  $v_5$  and vertex  $v_5$  is connected to vertex  $v_6$  then the color of vertex  $v_6$  cannot be similar to the color of vertex  $v_7$ . Vertex  $v_6$  is not connected to vertex  $v_8$ , so the color of vertex  $v_6$  can be similar to the color of vertex  $v_8$ , which is the color no.3.

Based on the graph coloring guidelines described above, there are 14 colors applied. This means there are 14 shifts of examination, as explained below :

Warna	Verteks
1	$v_3, v_{21}$
2	$v_5, v_7$
3	$v_6, v_8, v_{22}$
4	$v_{10}$
5	$v_{14}$
6	$v_{15}$
7	$v_{16}$
8	$v_1, v_{11}$
9	$v_2, v_{12}$
10	$v_4, v_{13}$
11	$v_9, v_{17}$
12	$v_{19}$
13	$v_{20}$
14	$v_{18}$

Therefore, from the table, we can organize the examination shift then there is no students following more than 1 examination at the same time. The schedule is listed as follow :

SHIFT	COURSE LIST	NAME OF COURSES
1	3	Kalkulus II
	21	Geometri
2	5	Pend. Kewarganegaraan
	7	Statistika Matematika I
3	6	Konsep Teknologi
	8	Kalkulus Peubah Banyak
	22	Pengendalian Mutu
4	10	Metode Numerik
5	14	Statistika Komputasi
6	15	Statistika Non Parametrik
7	16	Pemograman Linier
8	1	Statistika Elementer
	11	Analisis II
9	2	Pengenalan Aplikasi Komputer
	12	Aljabar I
10	4	Fisika Dasar II
	13	Matematika Demografi
11	9	Pemograman Komputer II
	17	Rancangan Percobaan
12	19	Aktuarial
13	20	Permasalahan Nilai Batas
14	18	Kontrol Optimal

#### 4. Conclusion

The use of algorithm in the vertices coloring algorithm can be implemented as an application program used to solve the graph coloring such as in the examination examination schedule.

If the process of schedule arrangement is carried out manually, it will take a long time and careful effort. Thus, the application coloring program enables a faster and simpler method of coloring with minimum human error.

By implementing this program application, we are enabled not only in organizing the examination schedule but also in modifying other problems that can be solved by using the algorithm vertex coloring for graph.

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**Department of Mathematics  
Faculty of Mathematics and Natural Sciences,  
Andalas University, Indonesia**