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Some Wheel Related Graph and It's Local Edge Metric Dimension

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ABSTRACT

One of the mathematics branches that often used in daily life as a tool to make the models of problem easier to understand and solved is graph theory. One of the topic in graph theory is metric dimension. The extension of the metric dimension theory is a local edge metric dimension. Let the metric generator of graph G be a vertex $j \in W$, W is a non empty set, therefore for any two edges in graph G namely e_1 and e_2, we have d_$G(j, e_1 \neq d_G(j, e_2))$. The edge metric dimension of graph G is the minimum edge metric generator. In line with the concept of edge metric dimension, the local edge metric dimension is the development of edge metric dimension with special requirement. For every adjacent edges xy and yz in graph$G$, if it full fill $r(xy|W) \neq r(yz|W)$, the minimum cardinality of W is called as the local edge metric dimension of graph G. Here, we analyze the result of local edge metric dimension of some wheel related graph namely fan graph, semi jahangir graph, and jahangir graph

INTRODUCTION

Mathematics is concerned with ideas, structures, and logical thinking. Mathematics also deal with abstract concepts. Mathematics is a science that compiled in an axiomatic deductive manner. It begin with a base statement and then derived as certain axioms and equipped with various definitions. Based on these opinion, it can be said that mathematics grows and develops because of the thought process, therefore, logic is the basis for the formation of mathematics. One of the branches of mathematics that is often used in daily life as a tool to make problem models easier to understand and solve is graph theory.

Graph theory was firstly introduced by the Swiss mathematician Leonhard Euler in 1736, through his writings on solving the Konigsberg bridge problem which was difficult at the time and proved to be solved using graphs. The city of Konigsberg located in the eastern part of

Pruusia, Germany, has a river known as the Pregal River. The river divides the city of Konigsberg into four main landmasses and seven bridges connecting the four landmasses. The Konigsberg bridge problem proposed by Euler is how to pass the seven bridges exactly once from a certain land 2 and return to the previous land. The discussion invites many scientists to develop and apply graph theory to every problem in everyday life. for further explanation about graph you can see (Gross, et al , 2014), (Chartrand, et. al, 2000), (Hartsfield, 1994). One of the useful graph theory topic in real life is metric dimension. Metric dimension in real life can be applied in navigation system in transportation. Metric dimension can give an unique code in every node in graph G. Suppose two vertices u and v are vertices of a connected graph G. The distance between vertices u and v is defined as the shortest path from vertex u to v in G and denoted by $d(u,v)$. If given an ordered set $W = \{w_1, w_2, w_3, \dots, w_k\} \subseteq V(G)$ of the vertices in a connected graph G and vertices v in $V(G)$, then the representation of vertex v with respect to W is $r(v|W) = (d(v,w_1), d(v,w_2), \dots, d(v,w_k))$. If $r(v|W)$ for each vertex $v \in V(G)$ is different, then W is called the resolving set of $V(G)$. The minimum cardinality of the resolving set or basis of G is called the metric dimension (Chartrand, 2000), (Harary, 1976). By applying the concept of metric dimensions, the transportation can moves from one location to another on the plane by minimizing errors that occur in translating the instructions (codes) obtained from these stop location. For this reason, each location coordinate on the plane of motion of these transportation must provide a different and unique code. If the coordinate of the stopping location is seen as a vertext and the path traversed by the transportation is seen as an edge, then the plane of motion of the transportation can be represented as a graph.

The extension of the metric dimension theory is a local edge metric dimension. Let the metric generator of graph G be a vertex $j \in W$, W is a non empty set, therefore for any two edges in graph G namely e_1 and e_2 , we have $d_G(j,e_1 \neq d_G(j,e_2))$ (Kelenc, 2016), (Slater, 1975). The edge metric dimension of graph G is the minimum edge metric generator. In line with the concept of edge metric dimension, the local edge metric dimension is the development of edge metric dimension with special requirement. For every adjacent edges xy and yz in graph G, if it full fill $r(xy|W) \neq r(yz|W)$, the minimum cardinality of W is called as the local edge metric dimension of graph G (Adawiyah, et. al. 2009). The distance between the vertex and the edge is define as $d_G(e,v) = min\{d(x,v), d(y,v)\}$ where v is the

vertex and xy is the edge. The Wheel Related Graphs is a number of graphs which has a structural relationship with wheel graphs and also the wheel related graph has a special feature that consists of a center point connected to all points on the circle (Daoud, 2017), (Basavanagoud, 2020). In this research, we analyze the result of local edge metric dimension of some wheel related graph namely fan graph, semi jahangir graph, and jahangir graph.

METHODOLOGY

In this research, we use pattern recognition methods and deductive axiomatic methods. The deductive axiomatic method is a method used by applying the principles of deductive proof that apply in mathematical logic by using existing axioms, lemmas, and theorems which are then applied in solving a problem related to local edge metric dimension. This research is explorative and applied research. Explorative research is a research conducted with the aim of researching and reviewing data and new things that researchers want to know, such as formulating problems to be studied and deepening knowledge and looking for the latest ideas on topics to be researched and later research results can be used. as the basis for further research. Applied research is a type of research that aims to provide practical solutions to certain problems. The results of this study can be used to solve problems, develop theories, and open up possibilities for further research.

RESULT AND DISCUSSION

In this section, we discuss the breaf results about local edge metric dimension of some wheel related graph namely fan graph, semi jahangir graph and jahangir graph. The results are shown in the theorem form followed by the proof in each theorem. Here are the reseach results:

Theorem 3.1.

If $G = F_n$ is a fan graph with $n \geq 3$, then the local edge metric dimension of fan graph is $n - 1$.

Proof.

Fan graph denoted by F_n is a graph with $n + 1$ vertices and $2n - 2$ edges. Fan graph is a graph which obtained by connecting all the vertices of the path graph P_n to the point called the center point. Therefore, a fan graph consist of star graph and path graph as the sub graph. Let the fan graph vertex set be $\{c\} \cup \{x_i; 1 \leq i \leq n\}$ and the edge set $(F_n) = \{cx_i; 1 \leq i \leq n\} \cup \{x_i\, x_{i+1}; 1 \leq i \leq n - 1\}$. In order to proof the local edge metric dimension of fan graph, let we consider the local edge metric dimension of the fan sub graph.

We know that one of the fan sub graph is star graph. In order to prove the lower bound of local edge metric dimension of fan graph, we can analyze based on the sub graph of the fan graph. It has been explain in the previous, a fan graph consist of star graph and cycle graph as the sub graph. Thus, we consider the local edge metric dimension of the star graph which is $diml_E(S_n) = n - 1$. If we take a look, why we should consider the star graph as the sub graph of fan graph, it is because the maximum degree of fan is in the center of the fan graph. The center of the fan graph is the part of the star graph. Based on the definition of local edge metric dimension, the neighbourhood edges must have a different representation respect to the metric generator. If we have $diml_E(F_n) = n - 2$, there will be edges in the star graph as the sub graph of fan graph have the same representation because all the edges are adjacent. For example, if we have $diml_E(F_n) = n - 2$, and the edge metric generator of the fan graph is $\{x_i; 1 \leq i \leq n - 2\}$, we got the edge representation of cx_n and cx_{n-1} respect to edge metric generator are the same. Thus, we should have $n - 1$ edge metric generator in the fan graph. It can be concluded that $diml_E(F_n) \geq n - 1$.

Furthemore, we analyze the upper bound of local edge metric dimension of the fan graph. The fan graph vertex set be $\{c\} \cup \{x_i; 1 \leq i \leq n\}$ and the edge set $(F_n) = \{cx_i; 1 \leq i \leq n\} \cup \{x_i\, x_{i+1}; 1 \leq i \leq n - 1\}$. Let $\{x_i; 1 \leq i \leq n - 1\}$ be the edge metric generator of the fan graph. By having these edge metric generator, we will have representation of all edges in fan graph respect to the edge metric generator in the table 1.

Table 1. The code representation of all edges in fan graph F_n respect to the edge matric generator $\{x_i; 1 \leq i \leq n - 1\}$

e	$R(e\|S)$	Requirement
cx_1	$(0,\underbrace{1,\dots,1}_{n-2})$	
cx_i	$(\underbrace{1,\dots,1}_{i-1},0,\underbrace{1,\dots,1}_{n-i-1})$	$2 \leq i \leq n - 1$
cx_n	$(1,\dots,\underbrace{\dots 1}_{n-1})$	$n \geq 3$
x_1x_2	$(0,0,\underbrace{1,2,\dots,2}$	$n \geq 3$

e	$R(e\|S)$	Requirement
	$n-4$	
$x_i x_{i+1}$	$(2,\dots,2,1,0,0,1,2,\dots,2)$	$2 \le i \le n-2$
	$i-2$ $\quad$ $n-i-3$	

Based on table 1, we can see that all representation of all edges in the fan graph respect to the edge metric generator are distinct. Thus, we have $diml_E(F_n) \le n-1$. Since $diml_E(F_n) \le n-1$ and $diml_E(F_n) \ge n-1$, we can say that $diml_E(F_n) = n-1$. Figure 1 shows the local edge metric dimension of fan graph F_5. Based on the figure 3.1, we have vertex x_1, x_2, x_3, x_4 as the edge metric generator of fan graph F_5. We can see that all the adjacent edges have a distinct representation respect to the edge metric generator. Thus, we can say that the local edge metric generator of fan graph F_5 is 4.

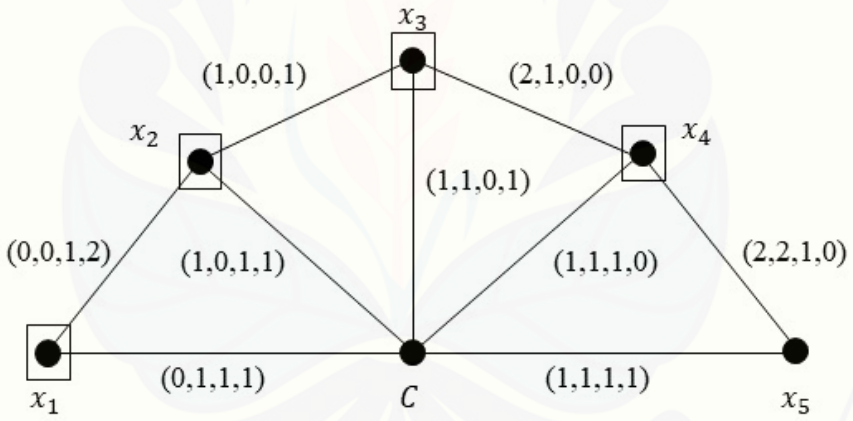

Figure 1. The local edge metric dimension of fan graph F_5

Theorem 3.2.

If $G = SJ_n$ is a semi Jahangir graph with $n \ge 3$, then the local edge metric dimension of semi jahangir graph is $n-1$.

Proof.

Semi jahangir graph denoted by SJ_n is a graph with $2n+1$ vertices and $3n-2$ edges. Semi jahangir graph is graph obtained by adding middle vertex in every adjecent vertex in fan graph except in the center vertex. Therefore, in line with fan graph, semi jahangir graph is h consist of star graph and path graph as the sub graph. Let the semi jahangir graph vertex set be $\{c\} \cup \{x_i; 1 \le i \le n\} \cup \{y_i; 1 \le i \le n\}$ and the edge set $E(SJ_n) = \{cx_i; 1 \le i \le n\} \cup \{x_i y_i; 1 \le$

$i \leq n\} \cup \{y_i x_{\{i+1\}}; 1 \leq i \leq n-1\}$. In order to proof the local edge metric dimension of semi Jahangir graph, let we do deep analysis of semi Jahangir graph each component.

First, let we make a deep anlysis of lower bound Jahangir graph edge metric dimension. We will prove that $diml_E(SJ_n) \geq n-1$. By considering the number of edge generator, let we supposed that $ml_E(SJ_n) \geq n-2$. Let we take the smallest number of edge metric generator $diml_E(S_n) = n-2$. If we have $diml_E(S_n) = n-2$, the edge metric genartor will be $\{x_i; 1 \leq i \leq n-2\}$. If we have only $n-2$ vertices as metric generator, and we have $E(SJ_n) = \{cx_i; 1 \leq i \leq n\} \cup \{x_i y_i ; 1 \leq i \leq n\} \cup \{y_i x_{\{i+1\}}; 1 \leq i \leq n-1\}$, the will be some edges in semi Jahangir graph which have the same representation respect to the metric generator especially in cx_i edges. We know that all edges in cx_i are adjacent. If we have only $n-2$ vertices as edge metric generator for example $\{x_i; 1 \leq i \leq n-2\}$, there will be cx_n and cx_{n-1} that have the same representation respect to the edge metric generator. Thus, we should have $n-1$ edge metric generator in the semi jahangir graph. It can be concluded that $diml_E(SJ_n) \geq n-1$.

Then, we analyze the upper bound of local edge metric dimension of the semi jahangir graph. the semi jahangir graph vertex set be be $\{c\} \cup \{x_i; 1 \leq i \leq n\} \cup \{y_i; 1 \leq i \leq n\}$ and the edge set $E(SJ_n) = \{cx_i; 1 \leq i \leq n\} \cup \{x_i y_i ; 1 \leq i \leq n\} \cup \{y_i x_{\{i+1\}}; 1 \leq i \leq n-1\}$. Let $\{x_i; 1 \leq i \leq n-1\}$ be the set of edge metric generator of the semi jahangir graph. By having these edge metric generator, we will have representation of all edges in semi Jahangir graph respect to the edge metric generator in the table 2.

Table 2. The code representation of all edges in Semi Jahangir graph SJ_n respect to the edge matric generator

e	$R(e\|S)$	*Requirement*
cx_1	$(0,\underbrace{1,\dots,1}_{n-2})$	
cx_i	$(\underbrace{1,\dots,1}_{i-1},0,\underbrace{1,\dots,1}_{n-i-1})$	$2 \leq i \leq n-1$
cx_n	$(\underbrace{1,\dots,\dots 1}_{n-1})$	$n \geq 3$
x_1y_1	$(0,0,\underbrace{1,2,\dots,2}_{}$	

e	$R(e\|S)$	*Requirement*
	$n-3$	
x_iy_i	$(2,\dots,2,0,1,1,\dots,1)$ $i-2$ $n-i-3$	$2 \le i \le n-2$
y_1x_2	$(1,0,2,\dots,2)$ $n-4$	
y_ix_{i+1}	$(2,\dots,2,1,0,0,1,2,\dots,2)$ $i-2$ $n-i-3$	$2 \le i \le n-1$
$y_{n-1}x_n$	$(2,\dots,2,1)$ $n-2$	$n \ge 3$

Based on table 2, we can see that all representation of all edges in the semi jahangir graph respect to the edge metric generator are distinct. Thus, we have $diml_E(SJ_n) \le n-1$. Basd on the anlysis of lower bound and upper bound of local edge metric dimension, we know that $diml_E(SJ_n) \le n-1$ and $diml_E(SJ_n) \ge n-1$, we can say that $diml_E(SJ_n) = n-1$. Based on the figure 2, we have vertex $\{x_1, x_2, x_3, x_4\}$ as the edge metric generator of semi jahangir graph SJ_5. We can see that all the adjacent edges have a distinct representation respect to the edge metric generator. Thus, we can say that the local edge metric generator of semi jahangir graph SJ_5 is 4.

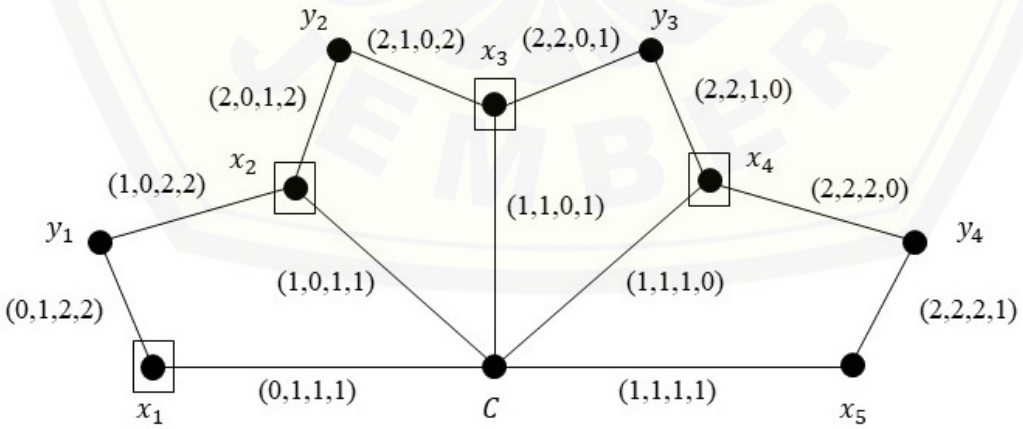

Figure 2. The local edge metric dimension of fan graph SJ_5

Theorem 3.3.

If $G = J_n$ is a Jahangir graph with $n \geq 3$, then the local edge metric dimension of jahangir graph is $n - 1$.

Proof.

Jahangir graph denoted by J_n is a graph with $2n + 1$ vertices and $3n$ edges. Jahangir graph is a graph which obtained from a wheel graph by adding a vertex in every two adjacent vertex except in the center vertex. A jahangir graph consist of center vertex and spoke. Let the jahangir graph vertex set be $\{c\} \cup \{x_i; 1 \leq i \leq n\} \cup \{y_i; 1 \leq i \leq n\}$ and the edge set $E(J_n) = \{cx_i; 1 \leq i \leq n\} \cup \{x_i y_i; 1 \leq i \leq n\} \cup \{y_i x_{\{i+1\}}; 1 \leq i \leq n-1\}$. If we analyze and observe the jahangir graph, we can see that jahangir graph consist of star graph and cycle graph as the subgraph. In order to proof the local edge metric dimension of jahangir graph, let we consider the local edge metric dimension of the jahangir sub graph.

In order to prove the local edge metric dimension of Jahangir graph, we shuld show the lower bound and upper bound of local edge metric dimension of Jahangir graph. First, let we analyze the lower bound of loacal edge metric dimension of jahangir graph. It will be shown that $diml_E(J_n) \geq n - 1$ by using contradiction. Let we assume that $diml_E(J_n) \geq n - 2$ and we choose $diml_E(J_n) = n - 2$. If we have the local edge metric dimension of Jahangir graph is $n - 2$, there will be two condition of edge metric generator placement such as:

a. Suppose that all the edge metric dimension of the Jahangir graph are place in the spoke of the Jahangir graph. We know that all edges connected with the center vertex are adjacent. If we have only $n - 2$ edge metric generator, there will be two edges in the star graph which have the same representation. For example, if we have $\{x_i; 1 \leq i \leq n - 2\}$ as the edge metric generator, there will be cx_n and cx_{n-1} which will have the same representation respect to the edge metric generator. Thus, it is contradiction.
b. Supposes that the edge metric generator are placed in the center vertex of jahangir graph and in the spoke of jahangir graph. By having these edge metric generator, same as previous condition, there will be two edges in the star graph which have the same representation since all the edges in the star graph are adjacent. Thus, it is contradiction.

Based on those two conditions, thus, we should have $n-1$ edge metric generator in the jahangir graph. It can be concluded that $diml_E(J_n) \geq n-1$. Then, we analyze the upper bound of local edge metric dimension of the jahangir graph. the jahangir graph vertex be $\{c\} \cup \{x_i; 1 \leq i \leq n\} \cup \{y_i; 1 \leq i \leq n\}$ and the edge set $E(J_n) = \{cx_i; 1 \leq i \leq n\} \cup \{x_i y_i; 1 \leq i \leq n\} \cup \{y_i x_{\{i+1\}}; 1 \leq i \leq n-1\}$. Let $\{x_i; 1 \leq i \leq n-1\}$ be the edge metric generator of the jahangir graph. By having these edge metric generator, we will have representation of all edges in jahangir graph respect to the edge metric generator in the table 3.

Table 3. The code representation of all edges in Jahangir graph J_n respect to the edge metric generator $\{x_i; 1 \leq i \leq n-1\}$

e	$R(e\|S)$	Requirement
cx_1	$(0,\underbrace{1,\dots,1}_{n-2})$	
cx_i	$(\underbrace{1,\dots,1}_{i-1},0,\underbrace{1,\dots,1}_{n-i-1})$	$2 \leq i \leq n-1$
cx_n	$(1,\underbrace{\dots,\dots}_{n-1}1)$	$n \geq 3$
x_1y_1	$(0,\underbrace{1,2,\dots,2}_{n-3})$	
x_iy_i	$(\underbrace{2,\dots,2}_{i-2},0,\underbrace{1,\dots,1}_{n-i-3})$	$2 \leq i \leq n-2$
y_1x_2	$(1,0,\underbrace{2,\dots,2}_{n-4})$	
y_ix_{i+1}	$(\underbrace{2,\dots,2}_{1-i},1,0,\underbrace{2,\dots,2}_{n-i-2})$	$2 \leq i \leq n-1$
$y_{n-1}x_n$	$(\underbrace{2,\dots,2}_{n-2},1)$	$n \geq 3$
x_ny_n	$(1,\underbrace{2,\dots,2}_{n-2},1)$	$n \geq 3$
x_1y_n	$(0,\underbrace{2,\dots,2}_{n-2},1)$	$n \geq 3$

Based on table 1, we can see that all representation of all edges in the jahangir graph respect to the edge metric generator are distinct. Thus, we have $diml_E(J_n) \leq n-1$. Since $diml_E(J_n) \leq n-1$ and $diml_E(J_n) \geq n-1$, we can say that $diml_E(J_n) = n-1$. Let we see an example of edge metric dimension of Jahangir graph j_n. Based on the figure 2, we have vertex $\{x_1, x_2, x_3\}$ as the edge metric generator of jahangir graph J_4. We can see that all the adjacent edges have a distinct representation respect to the edge metric generator. Thus, we can say that the local edge metric generator of jahangir graph J_4 is 4.

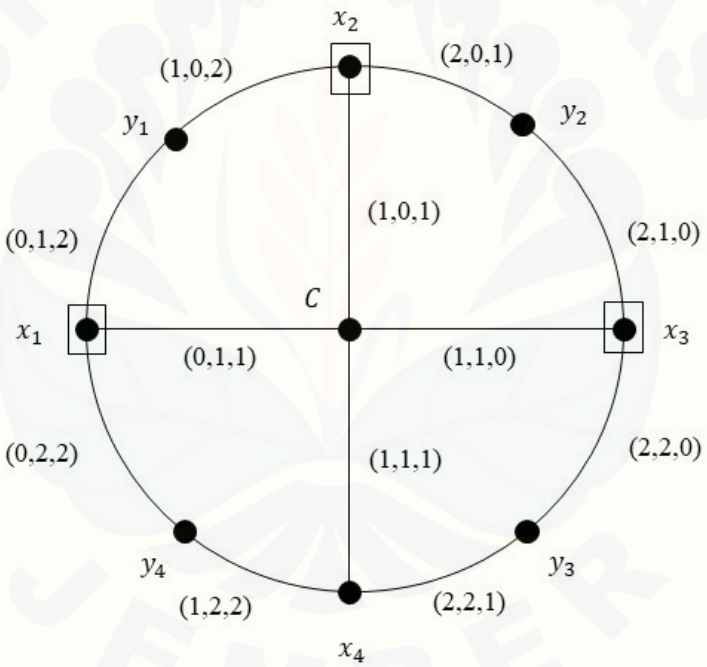

Figure 3. The local edge metric dimension of fan graph J_4

CONCLUSION

The metric dimension was first introduced by Harary and Melter in 1966. The study of the local edge metric dimension into an NP. Complete Problem means that it is not easy to get the local

edge metric dimensions of a graph of a certain shape. Therefore, to get the local edge metric dimensions of certain graph shapes or certain classes, an analysis of the subclasses is carried out first to make it easier to find the local edge metric dimensions of graphs in general. Some applications of resolving sets in chemistry are to represent chemical compounds. An example application of another metric dimension is to minimize the installation of fire sensors in a building. From the results of the discussion of local edge metric dimensions in semi jahangir, Jahangir and fan graphs, the following conclusions are obtained: the local edge metric dimension of fan graph, semi jahangir graph, and jahangir graph are $n-1$. There are still many problems related to the edge metric dimension of graph. The open problems are as follow:

Open Problem 1.

Find the characterization of local edge metric dimension of any graph G.

Open Problem 2.

Find the local edge metric dimension of any graph operations.

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