The Application of Graph in the Chronology of Life

Try Ajitiono - 13512052
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jl. Ganesha 10 Bandung 40132, Indonesia
13512052@std.stei.itb.ac.id

The very first graph theory came from Leonhard Euler's paper back in 1736. But the term "graph" itself was first introduced by James Joseph Sylvester in Nature-- his paper-- which was published in 1878. Ever since that day, graph theories have been thrived. Now, by combining graph and analogy, we can apply almost everything of its theories in the chronology of our life. But how?

Keywords - graph, life, chronology

I. Introduction

What is graph? According to Kenneth H. Rosen (2006), *graph G (V, E)* consists of *V*, a nonempty set of *vertices* (or *nodes*) and *E*, a set of edges with each edge has either one or two vertices associated with it, called its *endpoints*. An edge is said to *connect* its endpoints.

Graph has many types, such as simple graph, multigraph, pseudograph, simple directed graph, directed multigraph, and mixed graph. Its edge also has two types, directed and undirected. The difference is that directed edge has an arrow while undirected edge doesn't. The main function of the arrow is to show the direction of the graph, so the reader knows its path.

Now, from that basic concept of graph, we can make an analogy that vertex is a *checkpoint* of time, which means each vertex contains the information of time and what is currently happening during that time. A graph of time is shown below. But what author wants to show is not about graph as a *time-event*, but rather to show what events may occur after a event occurs. As an example, what event may happen if X is still doing his/her test although the test time is over? There are a lot of possibilities. The assistant may take his/her test forcefully, scold him/her to stop doing the test, or maybe write his/her name in a paper to reduce his/her score. The purpose of this paper is to show that graph can represent them.

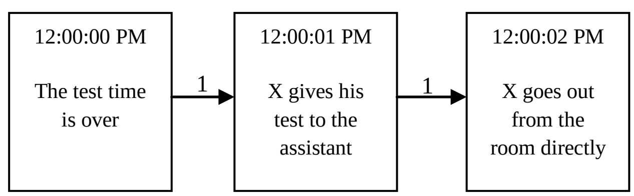

Figure 1. A simple graph of time

II. Basic Theories

1. Graph types

There are two types of graph edges, directed edges and undirected edges (both have been introduced above). A graph with undirected edges consists of:

- *Simple graph*, where multiple edges and loops aren't allowed.
- *Multigraph*, where multiple edges are allowed but loops aren't.

- *Pseudograph*, where multiple edges and loops are both allowed.

Meanwhile, a graph with directed edges consists of:

- *Simple directed graph*, where multiple edges and loops aren't allowed.
- *Directed multigraph*, where multiple edges and loops are both allowed.

A graph consists of directed edges and undirected edges is called a *mixed graph*.

2. Graph terminologies

There are several important terminologies in graph.

- *Adjacent*, when vertices *u* and *v* are connected by edge *e*. The edge *e* is called *incident with* vertices *u* and *v* when its endpoints are the vertices *u* and *v*.
- *Degree*, is the number of edges incident with it, except for a loop at a vertex, it contributes twice to the degree of that vertex.
- *Initial vertex* and *terminal vertex*, in (*u*,*v*), u is the *initial vertex* while v is the *terminal vertex*.
- *In-degree* and *out-degree*, only in directed graphs. In (*u*,*v*), *in-degree* means how many edges with *v* as their terminal vertex. *Out-degree* means how many edges with *u* as their initial vertex.
- *Complete graph*, when a simple graph contains exactly one edge between each pair of vertices.
- *Cycles* and *wheels*, a graph is called *cycle* if vertices $v_1,v_2,..,v_n$ connected by edges $\{v_1,v_2\},\{v_2,v_3\},..,\{v_n,v_1\}$. A graph is called *wheel* if a cycle has an additional vertex connected to every vertices.
- *Paths*, is a sequence of *n* edges from vertex *u* to *v* such that e_1 is associated with $\{x_0,x_1\}$, e_2 is associated with $\{x_1,x_2\}$, until en, which is associated with $\{x_{n-1},x_n\}$. In this term, $x_0 = u$ and $x_n = v$.
- *Connected*, an undirected graph is called connected if there is a path between every pair of distinct vertices of the graph.
- *Strongly connected*, a directed graph is called strongly connected if there are path from *a* to *b* and from *b* to *a* whenever *a* and *b* are vertices in the graph.
- *Weakly connected*, a directed graph is called weakly connected if there is a path between every two vertices in the underlying undirected graph.

3. Bipartite graph

A graph is called *bipartite* if no edge connects either two vertices in subset V_1 or subset V_2. The *complete bipartite* graph is the graph that has two subsets of vertices. There is an edge between two vertices if and only if one vertex is in the first subset and the other vertex is in the second subset. Figure 2 shows a complete bipartite graph of (*a*,*b*,*c)* as the first subset and (*d*,*e*,*f*) as the second subset.

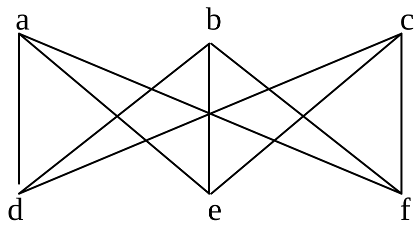

Figure 2. Complete bipartite graph

4. Subgraph

A graph is called *subgraph* when vertices and edges are removed from a graph without removing its endpoints of any remaining edges, a smaller graph is obtained.

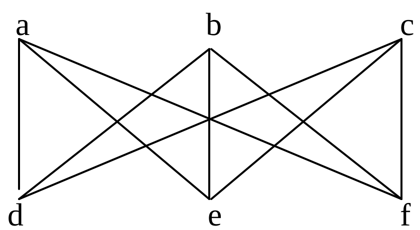

Figure 3. Complete bipartite graph

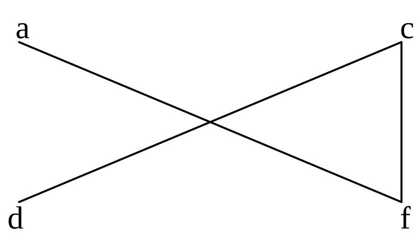

Figure 4. Subgraph of a complete bipartite graph

5. Union

A graph is called *union* when two or more graphs are being merged into a new graph, which means that new graph contains all vertices and edges from these graphs.

6. Weighted graph

Weighted graph is a graph that has a number assigned to each edge. Weighted graph has a correlation with *shortest path*. *Shortest path* is a set of edge(s) from *u* to *v* that have the least weight.

7. Chronology of life

As author has explained earlier, this life is nothing but a series of events. Every concurring event will lead to another event in the future, and so it goes. To represent them, we will need to use graph in Figure 1. Vertices in that graph show current time and event, while directed edges show how much time it takes to travel from one vertex to another, depending on the unit of time the graph uses. For example in Figure 1, each directed edge has 1 weight, which means it takes 1 second to travel from the initial vertex to the terminal vertex. Author will use *directed multigraph* during the explanation later on, because multiple edges are needed to represent possible future events.

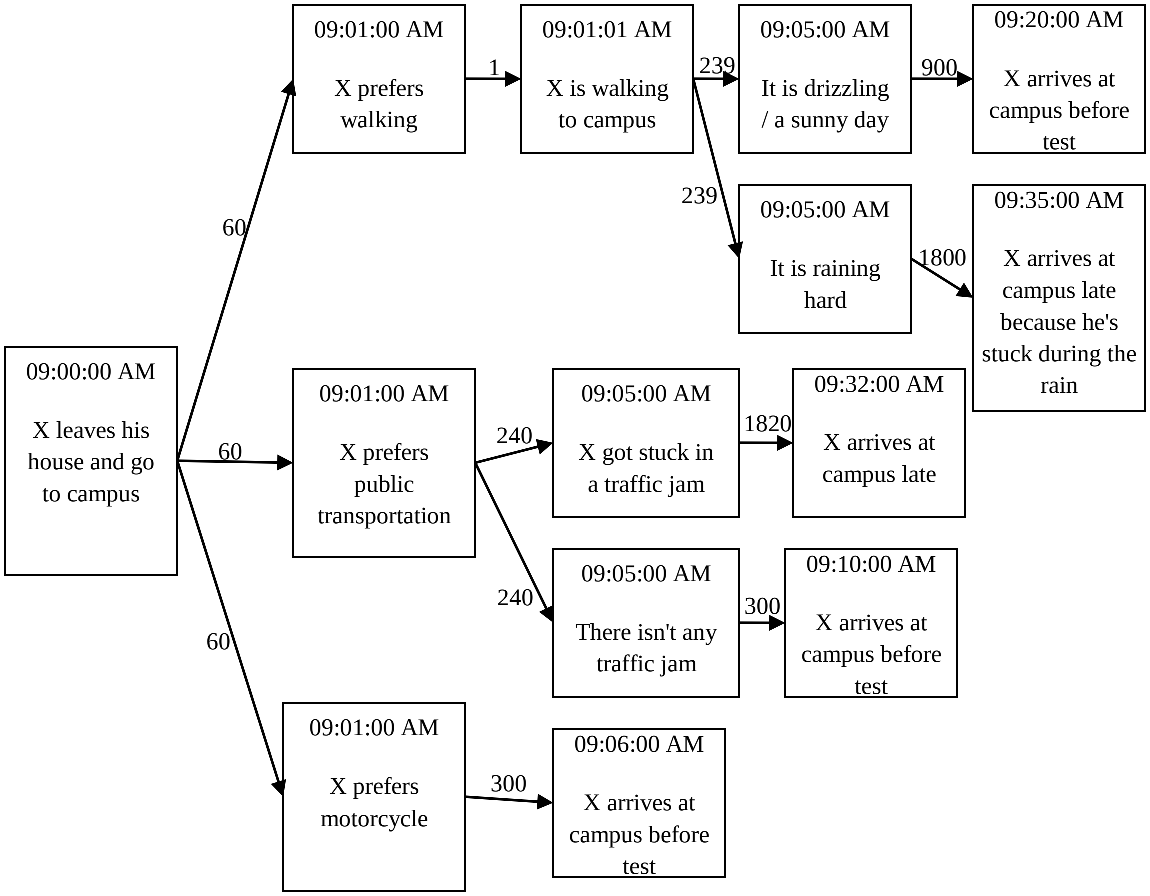

Figure 5. A multigraph shows that a decision can change the future

III. Application of directed multigraph in the chronology of life

1. Decision making

Figure 5 shows that a decision may cause many unpredicted events in the future. It is not only in that case, but actually everything that we do now will matter to the future. That's why we always have to choose a good decision. Note that every edge represents second(s) and not all possibilities are shown due to limited space.

A person X (male) wants to go to the campus to take the final test. He wonders about what transportation should he use. There are 3 choices: by walking, by public transportation, or by motorcycles. Figure 5 shows possible events that if X prefers walking.

The sky maybe bright, drizzling, or even raining hard (worst case) during his walk. If the sky is bright, X will still continue his walk. The same will happen when the sky is drizzling. X will arrive at campus on time. But when it is raining hard, X doesn't want to cross the rain because his clothes will get wet, so he is waiting until the rain is lighter. In this case, we assume that X doesn't bring an umbrella, raincoat, or poncho. But if he brings one, he can cross the rain and may arrive on time. Note that there are many other possibilities if X prefers walking, as an example, he falls accidentally and his ankle got dislocated. It will prolong his walk and might arrive late. It maybe even worse if the weather is not friendly to him.

If X prefers public transportation, Figure 5 shows that there are two possibilities. First, there will be a traffic jam. If he got stuck in a traffic jam, it means his arrival at campus will be delayed. But if there isn't any traffic jam, he will arrive at campus on time. These possibilities may happen both in good and bad weather, because bad weather often cause traffic jam.

The last one, if X prefers motorcycle, he will arrive at campus on time, disregarding the weather and the traffic jam, because motorcycle is a fast vehicle and usually each of motorcycle driver has a poncho in case it is raining. Moreover, motorcycle can pass through traffic jam easily because there will always be a gap between two distinct cars.

In author's point of view, X is a good decision maker if he takes a motorcycle when he has only 30 minutes left before the test begins. He is taking risks if he prefers walking or public transportation to campus.

2. Making alternative plans

When we are leading an organization or a committee, we have to make alternative plans in addition to our primary plan. The purpose is to minimize the negative impact when our primary plan fails. Imagine if we have only one plan for an event but suddenly there is an unexpected thing that ruins our event. It is important to make a good decision during that moment. But if we don't have alternative plans to run, our event will become worse before we found a new plan. Figure 6 shows a well-constructed plan for an outdoor tracking event. Plan A is colored white and plan B is colored gray. Plan A is used when the weather is good and plan B is used when the weather is bad.

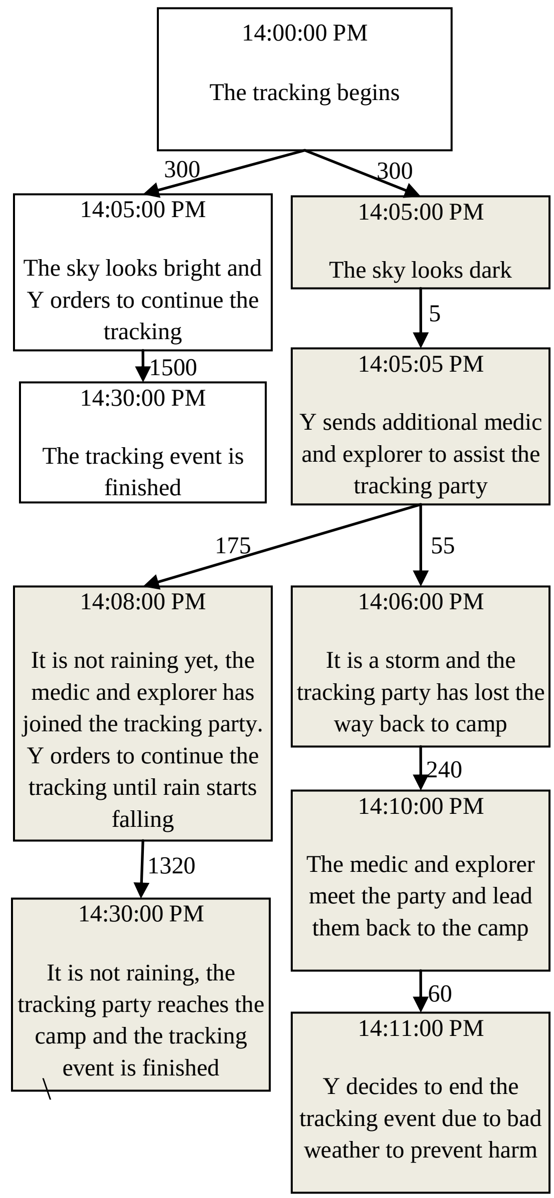

Figure 6. A graph of outdoor event tracking plans

IV. Conclusion

The conclusion is every decision we make and what will happen after can be represented with *directed multigraph*. Moreover, to anticipate unlikely things in the future, we can use the same graph as well to make alternative plans. Graph and chronology of life are similar because a graph has each pair of vertex connected each other with an edge, while life has each pair of event connected each other with something called "time".

V. Reference

1. Rosen, Kenneth H. 2006. *Discrete Mathematics and Its Applications, 6th Edition.* Singapore: McGraw-Hill.

PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

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Try Ajitiono
13512052