Comparing Three Simulation Model Using Taxonomy: System Dynamic Simulation, Discrete Event Simulation and Agent Based Simulation

Suliza Sumari[1], Roliana Ibrahim[2], Nor Hawaniah Zakaria[3], Amy Hamijah Ab Hamid[4]
Department of Information System, Faculty of Computing,Universiti Teknologi Malaysia,
[1]suliza4@gmail.com, [2]roliana@utm.my, [3]hawaniah@utm.my, [4]amyhamijah@gmail.com

Abstract-*Simulation model is one of the methods commonly used in Operational Research in order to represent the real situation that occurs in a system as well as to test the scenario based on different behavior. In this paper we discuss about three different models used in simulation: system dynamic, agent based simulation and discrete event simulation. The aim of this paper is to compare all these three methods in context of features, advantages, disadvantages and tools being used in each simulation method. The comparison of this paper also includes the classification of simulation model using taxonomy. Throughout this paper, we view a few software tools usually being used in a simulation like Vensim, ProModel and AnyLogic.*

General Terms- *Simulation*

Keywords- *Simulation; System dynamics; discrete event modeling; agent based modeling*

1. INTRODUCTION

Understanding the real system is not as easy as it in a few combinations of different people and different departments. In fact it takes a few steps or method and consumed a lot of time to understand the overall system especially the complex system because true existing system involved more than one agent or elements and events. Simulation models can help to obtain more understanding in a current system through the testing scenario using specific software tools. Basically, the main simulation methods that usually being used are system dynamic simulation, discrete event simulation and agent based simulation because these methods have the advantages which able to handle the uncertainty and variability of the system. Beside that, these simulation methods also using graphical user interface to show the communication and relationship in the current system [1]
Beside that, this paper also will build the taxonomy of simulation models since it has been used in research area for quiet long time since it is firstly introduced by Effective Practice and Organization of Care (EPOC) [2]. Basically, the purpose of using taxonomy is to classify the types of simulations, so that it will be easy to obtain an understanding about simulation. In this taxonomy, we stress on the features of the simulation and the software used in simulation. Fig. 1 shows the basic taxonomy of simulation models that will be discussed in this paper.

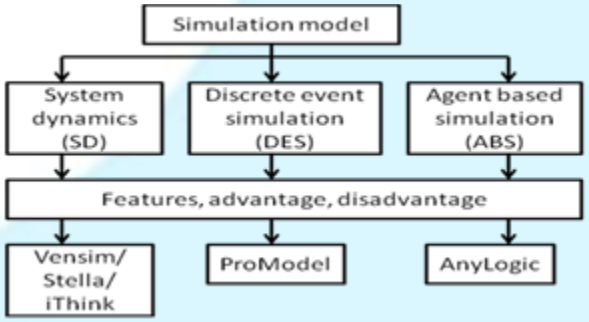

Figure 1- Taxonomy of simulation model

Simulation model can be said as an incorporating time that reflects to any changes that occurs over time [3]. Simulation may involve the use of logical, mathematical and also structural aspects of the systems. Beside that modeler also need to identify the parameter, so that in can represent the number or entity in current systems. Best time to implement and use simulation model are:

- When there is no analytic model that can provide an accurate calculation to analyze the situation
- The component of the system clearly defined as well as the interaction that occurs in the current systems
- When the real system is too complex to be analyzed and prediction of any changes are difficult to be done
- When a modeler need to make major changes in the new system. Simulation can be used to represent the existing system and the change can be made to the parameters

Basically there are few types of software tools can be applied in every simulation model. However, due to certain features in the software tools, there will have different function to any simulation model. Software deployment usually very important because it can help the modeler to see all interaction that occurs in any event or scenario and the description of the software can be translated to valuable information through the graph. Beside that by using certain software it also can show the real-time changes that occur in the certain events. On the other hand, the deployment of software also requires some skill and knowledge from the modeler to model their design. It depends on the type of the software that is used by the modeler because some of the software involved the programming language. In fact the modeler must identify first the elements and data that they should use, so that they can manipulate it to test the data for a certain scenario.

2. SIMULATION MODEL

Since this paper concern on three methods that usually implemented by other researchers, the next following section will discuss about these three model in details.

2.1 System Dynamic features

Basically system dynamic consist of two methods in order to make the implementation success. The first method is qualitative and the second is quantitative. The main reason to use these both method is to obtain more understanding regarding the current system as well as to identify the exact problem that occurs or might occur in the systems by using qualitative method. This qualitative method leads ~~to~~ the process of analyzing system by finding the loops and the interrelation for each parameter, as being showed in the fig. 2. Opposite from that, quantitative method is using stock and flow diagram in order to see the continuity that occurs in the system and it involve the use of numerical data that is relevant to systems. The data will be run in by using specific integer or graphical format or equation in the simulation models. During the simulation, the modeler is able to see the changes that occur based on the time and all changes will be analyzed. System dynamic is one of the ways to gain more understanding of the complex system in certain areas and it is usually used to find any opportunity to improve the weaknesses and overcome problems. This method focused on the feedback loop in order to see the cause and the reason for some events to happen. Besides that system dynamic will always related to computer simulation so that the real scenario that happen in the organization can be visualized. These two elements will be attached together in a system dynamic because of the feedback loop, the simulation of the events will be created. Fig.2 shows that the basic example of causal loop in the health care system whereby it describe the population of the patient which are in flow in and flow out. In the reinforcing loop, registration of the new patient described as a positive polarity which will increase the population of patients. Meanwhile in the balancing feedback loop it shows the negative polarity because once the patient discharge, the population of the patients will reduced and this process will make the system balanced. System dynamic also known as a model that has a continuous change in their state and it can be seen through the use of stock and flow series.

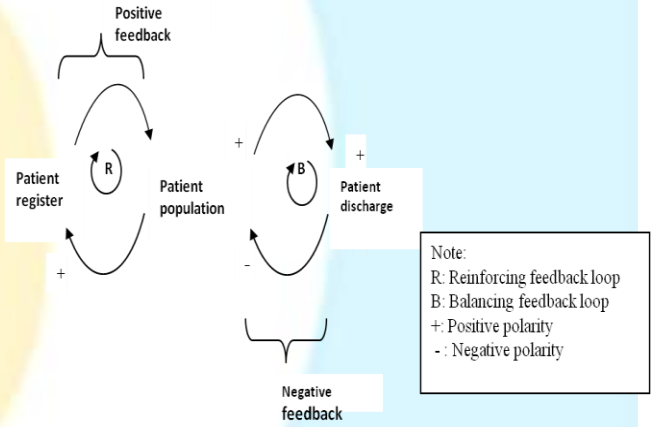

Figure 1- Feedback loop

Due to the advantages of system dynamic that is able to help researcher understanding the complex system, it is widely used by the policy maker in order to develop or improve the public policy by identifying the common question that might appears in an organization[4]. Other than that it also used in order to study about post-disaster management and simulate the situation before and after the disaster [5]. The ability of the system dynamic approach to help the modeler understanding the relevant factor that present in the system becomes one of the benefits of this technique. Moreover the factor that has been found can be used by the modeler to find out the structural system and analyze the effects of different type interaction [6].Since practicing system dynamic simulation require the modeler to understand and identify the problem in the system, it might be raised a concern, because if the problem is not clearly defined it may lead to the failure of implementing system dynamic. Another limitation of system dynamic is it might be quite complicated to be used when the big system came as it consist of too many complex scenario and consume a lot of time [7].

2.1.1 Stella and Vensim

Simulation software like Stella and Vensim are very common to those involved in system dynamic method. These softwares usually used to create the feedback and causal loop that shows the current situation occurs in the system. Some of the users claim that Stella which also known as "Ithink" is easier to learn rather that vensim, because Stella have friendly user help features whereby it

is good for the new learner. Instead, Vensim has been found a little bit complicated to be learned because the help features is not friendly as Stella. It has more features than Stella and for that reason it take a time for the new learner to use it for the first time. However, Vensim provide free software for a new learner who interested to getting used with Vensim called Personal Learning Edition (PLE) which can be downloaded in Vensim website. The similarity for both softwares, it is available for the Windows and Mac users. The advantage of using this kind of simulation software is it is easy for the modeler to build the model since the software provide an icon. Therefore they just need to drag and drop the icon into the interface and create a connection among the icons as well as edit the properties of icons. The frequent icon that is usually used is "cloud" which represents the source that available in the current system as shown in fig. 4.

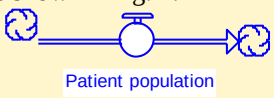

Figure3- Cloud symbols used in iThink

2.2 Discrete Event Simulation Features

Discrete event simulation is mostly used in Operational Research (OR) for over 40 years [8]. It is introduced in October 1961 by Geoffrey Gordon who is IBM's engineer whereby it came together with GPSS (General Purpose Simulation System) as a first version of discrete event modeling. This method shows the sequences of each event at a certain point of changes level that occur in the system in a discrete time [9]. Beside that discrete event mostly used in the area of operational or tactical level since in focus more on the process in the organization such as process that occurs at payment counters in shopping malls. Main focus in this simulation model is to show the process flow of event in the systems by using the method of top down approach and using a stochastic method. Beside that through this method, the entity will show a sequence of activities and also the period time for them to wait from one state to another state of event[1] . Through this sequence, the prediction of next event that is going to happen can be described. Since being introduced, discrete event simulation has been used for a wide purpose factor like study on Emergency Department activity at Level 1 trauma centers [10]. This study was done in order to identify the average tie for the patient to get the treatments [10]. In fact discrete event simulation also used by the modeler to find the best solution for the emergency department to enhance their efficiency [11].

In discrete event simulation, activity diagram being used as a conceptual model in order to describe the interaction that occurs to the entity in a certain event. Therefore, the researchers may be able to gain more understanding through the activity diagram showed because they can see the logic sequence that linked the entities event and also to resources. Basically, entities can be represented as a customer, documents, patients, products, transport or anything that have the tendency to initiate the flow of the events. For events, it can be described as a situation that occurs in the system such as treatment, payment, waiting or any situation that happen in a sequence while for the resources it also can be represented as a server, transport or equipments. Usually discrete event simulation requires a lot number of numerical data so that the result that they obtained is more accurate. All this connection between these three elements may produce an output like the waiting time spend by the entity in the system, the total usage of the resources and also the lengths of the queue facing by the entity. The interesting part in using discrete event simulation is that it uses the animations and graphic in order to represent the entities and the event that occurs in the real system. It is important to have a good and interactive model so that it can be understood by the user easily. Beside that in discrete event there is no limit to create as many entities that the modeler need because this model is concern more on the process that involve the entity and events. Another advantage of discrete event it is straightforward to be modeled once the problem that occurs in the organization has been clearly defined. Despite discrete-event simulation usually used by other researcher in their study, it is a bit disappointed to realize that this method does not really give an impact to the true variability and only help in central tendency measurement[9]. In fact other researchers state that discrete event simulation is not suitable to be used in order to analyze the model of human behavior because the main aim for discrete event is to focus on the process that occurs in the system[7].

2.2.1 Pro Model

In discrete event simulation, there are few elements need to be considered in order to make the simulation such as entity, resources, control elements, model execution and operations [12]. This element is a nature in the discrete event simulation modeling.

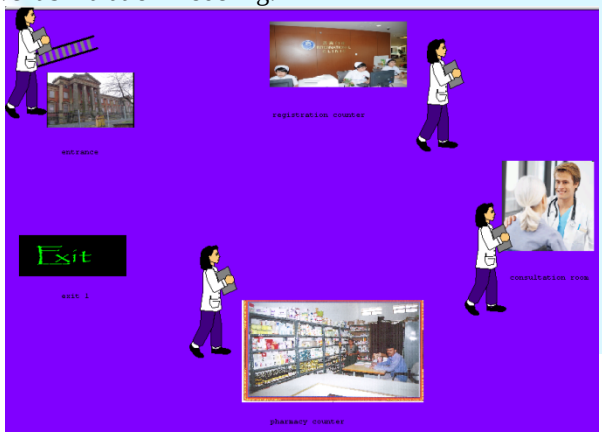

Figure 4-Example of entity used by the modeler in simulation

Replication	Total Exits	Current Qty In System	Avg Time In System (MIN)
1	111.00	5.00	21.25
2	111.00	5.00	19.21
3	111.00	5.00	21.12
4	111.00	6.00	19.47
5	111.00	5.00	20.41

Figure 5- Example of result from simulation

After the modeler able to identify this element with the respected value, they are able to run their simulation by using specific software. There is a lot of software can be used to simulate the discrete event simulation, however modeler usually will use software like ProModel and Arena to run their simulation [13] as this software is more simple to be used. T software enables the enabler to create the desired entity as many as they need. Beside that modeler also can use their own picture instead of using the picture that has been embedded in the software to make the simulation more interesting as was shown in fig. 5. At the same time the numeric data also will be keyed in before simulation can be done and produced a result to be analyzed like in fig. 6.

2.3 Agent Based Simulation Features

Another interesting method in simulation modeling was introduced in the early 1990's and it is known as an agent based simulation (ABS) model. However the agent best method was only start being used in simulation in 2000-2003 since it was just an academic topic in the year before. In order to capture the information in the system, this method implementing object oriented modeling like Unified Model Language (UML) and state charts to understand the current process that occurs and it also uses an agent in order to represent the scenario that occurs in the systems. The use of state chart also enables the modeler to the difference that occurs at each state, the transition among the agents, time and also the necessary events that emerge during the transition state. Agent based model also using an approach of bottom-up modeling because the basic thing need to be done is to identify the characteristic of the agents as well as the interaction that occurs among the agents [14]. This bottom-up method also used to identify the activities of every single agent in the system so that the modeler is able to focus on the rules of behavior and global behavior[15]. Beside that in agent based simulation method, they did not have any specific standard language to be used. In fact, the model usually will be represented in scripts. But it also depends on the software that is being used because some of them also use graphical editors in order to describe the behavior of each agent. Usually, the understanding to of the system can be obtained by describing the agents with a notation of state how the agents react to action at certain state[16].

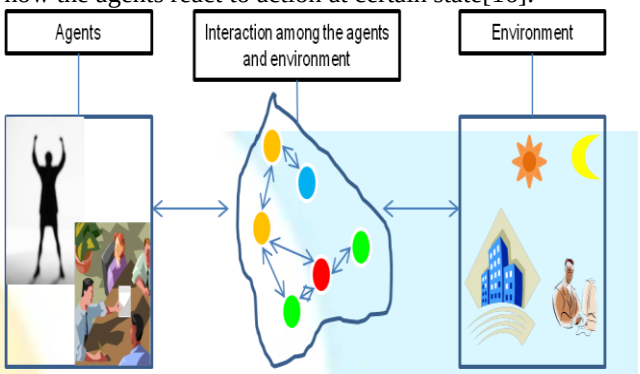

Figure-6 Interaction among the agents & environment

There are few advantages of agent based simulation method as it has been used in the business field because it has the ability to describe a real-problems that occurs in business and able to show the emergent event that produced by the interaction of individual entity [17]. Another field that implementing agent based simulation is an emergency department in healthcare. Basically this method is used help the respected officer to identify policy regarding on patient diversion as well as to analyze the patient's workflow [18]. Furthermore, hospital emergency department also found that this method useful for their operating system and may assist them to design decision support system (DSS) [19]. Thus, the emergency department is able to enhance their quality of services to the customers as well as increasing the efficiency of hospital even though the emergency department workflow keeps changing [20]. However there are some of the limitations in using agent-based method and the limitation may depend on the situation itself. For example, these methods require a lot of interaction among each agent and it need frequent communication so that the decision and activities was made at the right position. This method might not be selected because it involve large amount to be spend for communication [21]. Beside that this method requires the modeler to be more careful about implementing it in a big systems as it may require a high skill computation and consume a lot of time because large system usually consist of many types of units[17] .

2.3.1 Any Logic

AnyLogic is official software tools used in agent based simulation and it provides high flexibility for the user to choose the modeling technique. Basically AnyLogic also manage to support the implementation of other simulation models such as system dynamic and discrete event simulation [15]. Since ABS involve the use of UML and state chart, this software also able to support the function to create a state chart in order to describe the current situation of the agent and the process that occurs. Beside that AnyLogic also support Java language for modeling purpose [16].

3. SUMMARY AND CONCLUSION

Throughout this paper we attempt to fairly discuss about the classification of three simulation models using axonomy method, features and also software tools being used. We also discuss about few studies related to this three simulation method. Without bias to any method, this paper may gain more understanding for other researchers to find the source for their research. Beside that we provide a table to summarize all the features, advantages, disadvantages and the software used in each simulation model.

Table 1. Difference between three simulation model

System dynamics (SD)	**Discrete event simulation (DES)**	**Agent based simulation (ABS)**
Features		
-Used to gain more understanding on system behavior in long-term and the dynamic feedback behavior -Focus on the flow of the scenario in systems -Mostly used in policy making -Used at strategic level	-Used to enact the system that have a queue network as well as to compare and predict the scenario -Focus on the process that involve the use of queue -Mostly used in decision and prediction making -Used at an operational/ tactical level -Use top down approach	-Used to identify the interaction and operation among entities in more realistic and flexible ways -Focus on interaction that occurs in systems -Mostly used in business area -Use bottom up approach -Use bottom up approach
Advantages		
- Able to help in understanding complex systems -Able to identify the relevant factors that exist in complex systems -Scenario testing can be modified based in order to get the different results	-Easy for user to understand with the help of animations and graphics that build in the software package -Have unlimited flexibility to determine the behavior of entities -More straight forward to be modeled once the problem has been clearly defined	-Able to capture an emergence phenomena -Flexible to use -Able to describe the system with the natural ways
Disadvantages		
-Big system may become too complex to understand by the modeler -Failure in identifying problem may cause the failure in implementing system dynamics approach	-Less effective to show the impact of the true variability -Not very suitable to be used in analyzing model that is related to human behavior	-Involve high skills in computation for the use in large systems -Involve a lot of cost for communication
Software		
Vensim/ Stella/iThink	**ProModel**	**AnyLogic**
-Mainly used in system dynamics -Consist of icon that can be used to represent the flow and diagram of the scenario -Not much involve programming and use an equation	-Mainly used in discrete event simulation -Consist of animation and graphics that can be modified by the user -Not involve programming as the equation has been embedded in the system	-Mainly used in agent based simulation but also can be used to do discrete event simulation and system dynamics -Graphic is used in order to show the interaction that occurs among entities -Basically use java/c+ programming language -Build with 3D display

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Author's Biography

Suliza Sumari is a student in Universiti Teknologi Malaysia. Currently taking Information Technology Management as a major in her Masters course. She is now doing a project entitled "System dynamics in healthcare" for completing her Masters.

Dr. Roliana is a senior lecturer at the Faculty of Computing, Universiti Teknologi Malaysia. She has been servicing UTM for more than 10 years after a few years' experience working as a system developer in the industry. She received her PhD in Systems Science from Loughborough University

Nor Hawaniah Zakaria senior lecturer at Faculty of Computing, University Teknologi Malaysia. Interest research areas are database and data warehousing, software requirement, ontology engineering and information system development.

Amy Hamijah binti Ab. Hamid is a research officer from Malaysian Nuclear Agency (Nuclear Malaysia) in Technical Support Division. Currently, she is pursuing her tertiary studies in Ph.D of Information Systems under Faculty of Computing (FC), Universiti Teknologi Malaysia (UTM).