Discrete Event Simulation

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Abstract

Discrete-event simulation represents modeling, simulating, and analyzing systems utilizing the computational and mathematical techniques, while creating a model construct of a conceptual framework that describes a system. The system is father simulates by performing experiment(s) using computer implementation of the model and analyzed to draw conclusions from output that assist in decision making process. Discrete event simulation technologies have been extensively used by industry and academia to deal with various industrial problems. By late 1990s, the discrete event simulation was in doldrums as global manufacturing industries went through radical changes. The simulation software industry also went through consolidation. The changes have created new problems, challenges and opportunities to the discrete event simulation. This chapter reviews the discrete event simulation technologies; discusses challenges and opportunities presented by both global manufacturing and the knowledge economy. The authors believe that discrete event simulation remains one of the most effective decision support tools but much need to be done in order to address new challenges. To this end, the chapter calls for development of a new generation of discrete event simulation software.

Keywords: Discrete and interactive simulations, hybrid manufacturing systems, what-if-analysis, systems modeling.

1. Overview of Discrete Event Simulation Technologies

Discrete event simulation quantitatively represents the real world, simulates its dynamics on an event-by-event basis, and generates detailed performance report. It has long become one of the mainstream computer-aided decision-making tools due to availability of powerful computer [1]. Figure 1 illustrates the ways of study a system. Most often system is studied via experiment with actual model, or experiment with a model of actual system.

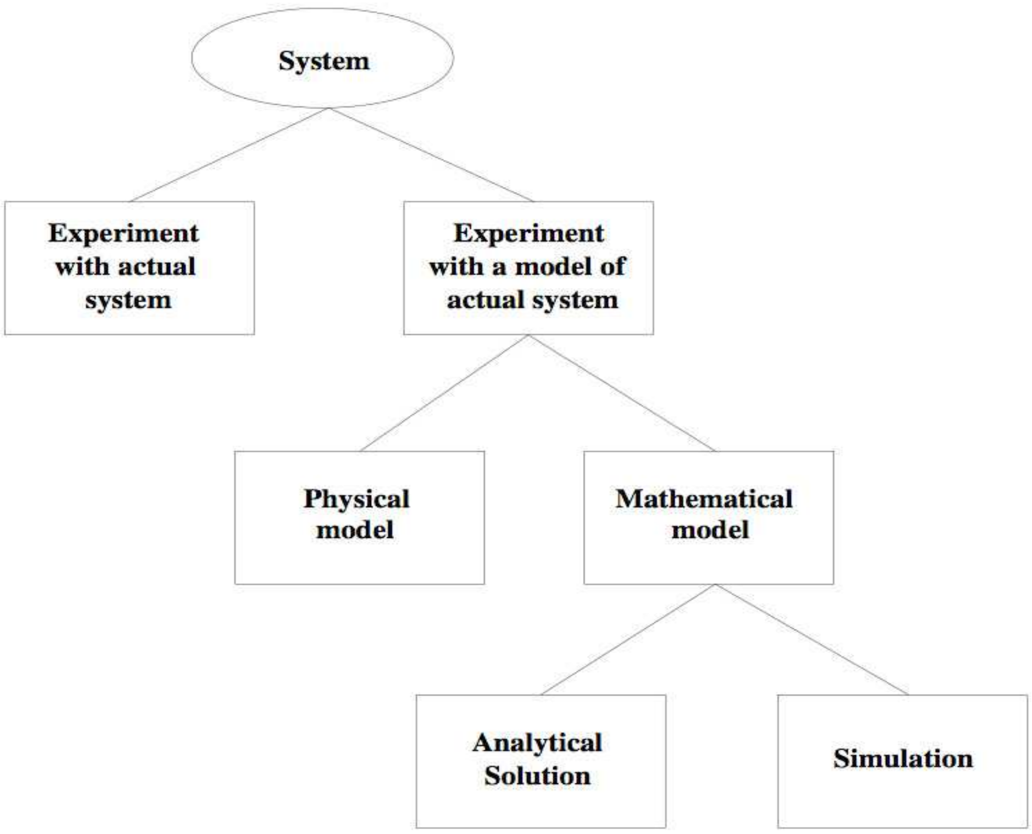

Fig. 1. Ways to study a system [15].

Figure 2, illustrates the model taxonomy used in the simulation process utilizing either deterministic or stochastic models.

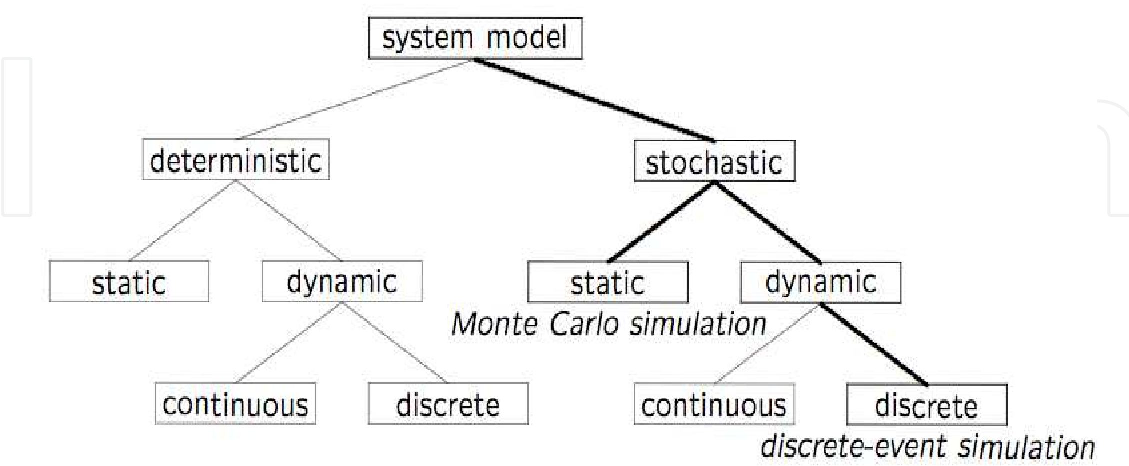

Fig. 2. Model Taxonomy [15]

The development of the discrete event simulation software has been evolved progressively since 1960s, and many systems have been developed by industry and academia to deal with various industrial problems. In brief, four generation of simulation software products have evolved [2], these being:

- ***1st Generation (late 1960s)*** - Programming in high level languages (H.L.L) such as FORTRAN. The modeler was obliged to program both the model logic and the code to control the events and activities, or 'simulation engine', in the model.
- ***2nd Generation (late 1970s)*** - Simulation languages that have commands like event control "engine", statistical distribution generation, reporting, etc. A model in the simulation language was compiled and then linked with the supplied subroutines to produce an executable model. Examples are GPSS (IBM), See Why (AT&T), AutoMod(ASI).
- ***3rd Generation (early 1980s)*** - Simulation language generators that are front-end packages that generate the code in a simulation language. The generated code is complied and then linked to produce an executable model. It reduced the model development time, but still required the modeler to master all aspects of the simulation mechanism. Examples are SIMAN (Systems Modeling), EXPRESS (AT&T).
- ***4th Generation (late 1980s)*** - Interactive simulation packages that enable "what you see is what you get", allow models to be modified at any time, speed up 'what-if' analysis. The simulation models can be built very quickly by industrial managers and engineers, thus encouraging those people with knowledge and first hand experience of the problem to build the model themselves. The example is WITNESS (AT&T), ARENA (Systems Modeling).

By mid 1990s, the virtual reality technology had created a new excitement among the simulation community. A significant amount of effort was made in developing an integrated simulation environment by which engineers can simulate product design and manufacture without going through different simulation packages. The two leading simulation software vendors at that time, Lanner Group and Deneb Inc., announced a plan to jointly develop a new generation of simulation software to support both process and detailed simulation with superior modeling and graphic capabilities. However, the excitement was soon overshadowed by unprecedented changes in manufacturing industries as a result of globalization. The simulation software vendors went through the industrial consolidation. AutoSimulation, System Modeling, Simple++, Deneb, are now part of large corporations. There are new breed of vendors with different business models and using internet for online product sales and support, noticeably Simul8 Inc.

Overall, there is no significant development in the discrete event simulation technologies and software since the 4^{th} generation. On the other hand, tremendous changes in business environment have presented new challenges and opportunities to the discrete event simulation as discussed below.

The paper presents in first section the review of discrete event simulation technologies. The second section discusses the applications of discrete event simulations in manufacturing sector and in the third section in education sector. In last two sections four and five, authors discuss future opportunities and conclusions.

2. Applications of Discrete Event Simulation in Manufacturing Sector

Discrete event simulation is traditionally used for industrial applications. In the 1980s and 1990s, there had been a rapid development of advanced manufacturing technology in industrialized countries: CAD (Computer-aided Design), CAM (Computer-aided Manufacture), AGV (Automatic Guided Vehicle), Robotics, FMS (Flexible Manufacturing System) and CIM (computer integrated manufacturing) in industrialized countries. The same can be said about the discrete event simulation technologies. Many companies had invested heavily in new technologies in order to make their manufacturing operations flexible. The discrete event computer simulation software was the tool to help managers make right decisions. Every production manager wanted to improve productivity in terms of higher throughput, shorter lead time, low work-in-process and high resource utilization. Through simulation, they could evaluate behavior of a manufacturing process under different sets of conditions; carry out 'what-if' scenario analysis in order to identify better physical configuration and operational policies. Overall the discrete event simulation software has been used in the following areas [3]:

1) Design and evaluation of new manufacturing processes.
2) Performance improvement of existing manufacturing processes, for example, feasibility study of an automated material handling system.
3) Establishment of optimum operational policies, for example, studying how many Kanban cards should be introduced on production shop floor in order to reduce work-in-progress.
4) An algorithm (or engine) to support production planning and scheduling.

A survey sponsored by the Department of Trade and Industry of the UK showed that the simulation modeling is used at all levels of management in the 500 largest corporations in the United States. It also found that where simulation has been used, capital costs were saved between 5% and 10% [4]. Manufacturing sector was the main market for the discrete event simulation software.

Changing business environment and new challenges: By late 1990s, the manufacturing landscape started to change rapidly, with China emerged as the "world manufacturing base". Many corporations have either outsourced their productions to third party or relocated their production lines to low-wager countries. One example is Motorola Inc. In the 1990s Motorola run 6 plants in Singapore, Malaysia and Philippines. The managers and engineers had used the discrete event simulation software for productivity improvement. Since early 2000s, Motorola went through several rounds of restructure. Now most of the plants are owned and run by two corporations spin-off from Motorola, On Semiconductors Corp and Freescale Semiconductors Corp. For those that remain in Motorola, some production lines have been relocated to China and some have been outsourced to sub-contract manufactures. Essentially Motorola does not run any manufacturing operations in Singapore, Malaysia and Philippines. The company has set up Global Supply Chain Control Office in Singapore to manage "its global third party component procurement activities"[5].

When a company is going through transformation, applications of discrete event simulation are always in doldrums. The large scale of "industrial transformation" has led to new problems to managers and new challenges to discrete event simulation technologies, as described below:

1). **Virtual corporation:** Global manufacturing and supply chain simply means multiple locations and multiple parties involved in global supply-chain. It also means complicated relationships among all parties, so called "virtual corporation". With zero inventory and just-in-time practice, all parties work under pressure. It would be ideal if all parties to understand behavior of the entire supply chain and impacts from their individual operations on the supply chain. It requires each of the parties to model an individual operation and to share the model and data with the others. It is no longer an isolated model but the *distributed modeling and simulation*. There are research works in the distributed modeling and simulation, noticeably, High Level Architecture (HLA), "the standard architecture for defense programs in the United States" [6]. Recently efforts have been made in applying HLA to industrial applications [7, 8].

2). **Hybrid manufacturing systems:** Many corporations have shut down highly automated plants in industrials countries and shifted production to low-wage countries where operations are primitive with limited managerial and engineering skills. What has emerged in low-cost countries is a mixture of advanced machinery and abundant of labors, a hybrid manufacturing system. Typically, advanced machines are used to carry out certain processes where quality consistency or high precision is critical, whilst all auxiliary processes and material transfer are done manually. The hybrid manufacturing system proves to have much higher responsive flexibility than an automatic manufacturing system, that is, the ability to increase or reduce production capacity rapidly and significantly.

Historically the discrete event simulation software was developed to model and simulate automate manufacturing processes. In a hybrid manufacturing system, human factors play a prominent role and are more important than advanced machines in influencing the system performance. Therefore it is critical to model human performance with different level of skills and under various working conditions.

There are many studies on human performance modelling, for example, the work by the human performance modelling technical group of the Human Factors and Ergonomics Society, by the International Society for Performance Improvement. However, the discrete event simulation software has not taken the findings into account and it remains problematic to model the human performance. At present, commercial discrete event simulation software are not able to handle these issues both effectively and efficiently. Much more work need to be done to make the discrete event simulation software capable of modeling *all* manufacturing activities in ear of globalization.

3. Applications of Discrete Event Simulation in Service Sector

Whilst manufacturing sector is on the decline, service sector in industrialized countries has been expanding fast. The scale of operation has been increased significantly and the nature of operation has become very complicated. Managers have tried to balance excellent customer service with operational efficiency (meaning shorter processing time, less waiting time for customers and higher resource utilization). Many of them have found that discrete event simulation can help them make right decision. In the way similar to manufacturing applications, they use the discrete event simulation software to model their business processes and evaluate behavior of the service system under different sets of conditions;

carry out 'what-if' scenario analysis in order to identify better way to deliver their services [9, 10]. Some examples are:

- Banking and finance services: call center modeling & simulation, bank branch modeling & simulation, simulation of vehicle routing (cash carriage services) and number of cash carriage services per routing, simulation study of cash management of ATM such as minimum re-order point, optimum budget and so on.
- Healthcare and hospitals: in-patient and out-patient waiting list modeling, bed planning, new/existing facility modeling, hospital and service expansion/merger, operation theatre scheduling etc.
- Logistic and transportation: shipping strategy analysis, design of sorting centers and/or material handling system, manpower and facility planning etc.
- Public sector: modeling of police emergency response, optimization of armed response vehicle deployment, re-engineering criminal investigation process etc.

Modeling of service operations is different from that of manufacturing operations, as described below:

1) **Process flow**: A manufacturing process is always associated with physical flows of materials/components and therefore can be easily identified. It may not be the case for many service applications where business activities are information-based and triggered by an external or internal event such as a written or oral request. The current solution is to use a business process mapping tool to capture the business process and then convert the process model to the discrete event simulation model [KBSI, Lanner].

2) **Process related data such as processing time:** In a manufacturing company, industrial engineers are responsible for time study, setting processing time and balancing flow. Most of service companies do not hire industrial engineers or have equivalent position within organizations. As a result, much of the process related data are not readily available.

3) **Knowledge workers:** In many service companies, employees work primarily with information or develop and use knowledge. They are *knowledge workers,* a term coined by Peter Drucker. A knowledge worker tends to be self-motivated, work interactively and make decisions constantly. How to represent knowledge workers and human-decision making process in discrete event simulation remains a subject under study [10].

In the postindustrial economy, the service sector makes up more than half of the American economy. Since mid 1990s, the sector has generated almost all of the US economy increases in employment. Knowledge workers are now estimated to outnumber all other workers in North America by at least a four to one margin [11]. Thus, there is a great potential for discrete event simulation technologies in service sector. However, new approach and techniques are required to model and simulate knowledge workers and their decision-making processes.

4. New Opportunities for Discrete Event Simulation

The changing business environment and technological developments have created other opportunities for discrete event simulation technologies. In particular, we would highlight following two areas::

1) **Business Intelligence (BI) systems:** Throughout 1990s ERP systems had taken the centre stage in the electronic enterprise. Corporations have spent a great amount of resources and effort in implementing ERP systems. Now many corporations have a solid IT infrastructure

in place with a high degree of information integration. From the discrete event simulation viewpoint, it is much easier to get the data to drive a simulation model than before as the data is readily available from the ERP system. The management focus has shifted from getting information to making intelligent use of information for improving business performance. Business Intelligence (BI) software helps companies have a more comprehensive knowledge of the factors affecting their business, such as metrics on sales, production and internal operations. However, to make better business decision, one has to consider how to deploy resources to the opportunities being identified, or *process capability*. The discrete event simulation is an ideal platform to support managers to make decisions on the resource deployment or process capability. Therefore a complete Business Intelligence (BI) system should include both the data analysis capability and a predictive technology. The data analysis capability gathers and analyzes large quantities of unstructured data such as production metrics, sales statistics, attendance reports and customer attrition figures with emphasis of having a comprehensive knowledge of the factors affecting business. The predictive technology enables managers to evaluate different options in order to make right business decisions.

2) **Simulation-based Education:** When a corporation has decided to outsource production to third party, a major implication is how to sustain the in-house engineering knowledge and expertise in the long term, provided that the corporation still wants to design and develop their own products. Erosion of engineering knowledge and expertise is the challenge not only to corporations but also to educational establishments in industrialized countries. One possible solution is to create a simulated manufacturing environment for executives, managers, engineers and students to experience and learn how to manage manufacturing and logistical operations. Discrete event simulation is an ideal platform for such an application. Moreover, there is abundance of simulation cases and models which can be adopted for the engineering and business education. Given current advances in Internet and Telecommunications Technologies, the future of logistics and manufacturing process will become fully automated [12, 13].

5. Conclusions

Discrete event simulation technologies have been up and down as global manufacturing industries went through radical changes. The changes have created new problems, challenges and opportunities to the discrete event simulation. On manufacturing applications, it is no longer an isolated model but the distributed modeling and simulation along the supply-chain. In order to study the hybrid manufacturing systems, it is critical to have capability to model human performance with different level of skills and under various working conditions. On service applications, the most critical part is to model knowledge workers and their decision making process.

The authors believe that discrete event simulation continue to be one of the most effective decision support tools both in global manufacturing and knowledge economy. There are new opportunities for discrete event simulation such as business intelligence systems and simulation-based education. At the same time, there is a strong need to develop a new generation of discrete event simulation software by taking account of changes in application environments.

Acknowledgment

Author wishes to express his sincere gratitude to colleagues in the industry and academia for the support provided during this work.

6. References

[1] Law, A. M. and Kelton, W.D. (2000) "Simulation Modeling & Analysis" 3rd Ed. McGraw-Hill.

[2] Wang, M. and Sun, G. (1993). "Manufacturing Simulation: An Effective Tool for Productivity Improvement". In *Proceedings of 3rd International Microelectronics & Systems '93 Conference.* August 1993 Malaysia.

[3] Wang, M., Sun, G. and Nooh, M. (1995). "Application of Simulation to Reduce Manufacturing Cycle Time" In *Proceedings of 4th International Microelectronics Systems'95 Conference*. May 1995 Malaysia

[4] "Manufacturing Simulation in the UK" (1992). by UK Ministry of Trade and Industry.

[5] "Motorola launches $60 million supply chain center in Singapore" (2006) *Logistics Today* July 2006, Published by Penton Media, Inc New York

[6] Fujimoto, R. M.(2000) "Parallel and Distributed Simulation Systems" John Wiley & Sons, Inc.

[7] Chen, D.; Turner, S.J.; Boon Ping Gan; Wentong Cai (2004) "HLA-Based Distributed Simulation Cloning" Distributed Simulation and Real-Time Applications, 2004. DS-RT2004. Eighth IEEE International Symposium on Volume, Issue, 21-23 Oct. 2004 Page(s): 244 – 247.

[8] Lendermann, P. et al. (2003) "Distributed Supply Chain Simulation as a Decision Support Tool for the Semiconductor...Journal of Simulation 2003; 79: pp126-138, Published by Sage Publications.

[9] "Transforming the way: Delivering a better and quicker way for organizations to improve service delivery and process performance". A white paper by Lanner Group

[10] Swank, C.K. (2003) "The Lean Service Machine" Harvard Business Review October 2003, pp123-139.

[11] Robinson, S. et al (2007). "Modeling Human Interaction in Organizational Systems". from Fishwick, P.A "Handbook of Dynamic System Modeling". Publisher: Chapman & Hall/CRC (June 1, 2007), pp113-122

[12] Haag, S et al (2006) Management Information Systems For the Information Age (3rd Canadian Ed.). Canada: McGraw Hill Ryerson, p3.

[13] Babulak, E: "*Quality of Service Provision for the Modern Telecommunications Infrastructures in Transport and Industrial Logistics Solutions*", **invited and presented Keynote Addres,** the International Conference on Logistics LOGI 2005, February 15-16, 2005, Czech Republic

[14] Babulak, E: "*E-Manufacturing for 21st Century, State-of-the-Art and Future Directions*" **invited and presented Keynote Address,** the First International Conference on Management of Manufacturing Systems presentation, Presov, Slovakia, November 18th – 19th, 2004.

[15] Fishman, G: *Discrete-Event Simulation: Modeling, Programming, and Analysis*, 2001

Web sources

[1] Simul8 Corporation: www.simul8.com
[2] The human performance modelling technical group, The Human Factors and Ergonomics Society: www.cogsci.rpi.edu/cogworks/hpmsite/
[3] The International Society for Performance Improvement (ISPI): www.ispi.org
[4] Lanner Group: www.lanner.com
[5] KBSI Inc: www.kbsi.com

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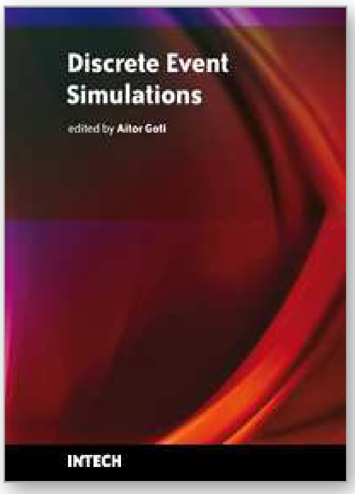

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Edited by Aitor Goti

ISBN 978-953-307-115-2
Hard cover, 330 pages
Publisher Sciyo
Published online 18, August, 2010
Published in print edition August, 2010

Considered by many authors as a technique for modelling stochastic, dynamic and discretely evolving systems, this technique has gained widespread acceptance among the practitioners who want to represent and improve complex systems. Since DES is a technique applied in incredibly different areas, this book reflects many different points of view about DES, thus, all authors describe how it is understood and applied within their context of work, providing an extensive understanding of what DES is. It can be said that the name of the book itself reflects the plurality that these points of view represent. The book embraces a number of topics covering theory, methods and applications to a wide range of sectors and problem areas that have been categorised into five groups. As well as the previously explained variety of points of view concerning DES, there is one additional thing to remark about this book: its richness when talking about actual data or actual data based analysis. When most academic areas are lacking application cases, roughly the half part of the chapters included in this book deal with actual problems or at least are based on actual data. Thus, the editor firmly believes that this book will be interesting for both beginners and practitioners in the area of DES.