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ENHANCING SIMULATION AS IMPROVEMENT AND DECISION SUPPORT SYSTEM TOOL

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ABSTRACT

Lecturing a Discrete Event Simulation course implies some challenges for the instructors. These challenges implies taking decisions from the design of the course to the selection of the didactic strategy to be used in each lecture. On the other hand, the use of games during a lecture make easier the understanding of simulation concepts. Moreover, games may be designed to show the impact of changing the value of the decision variables, similar to a decision support system software. This paper presents a methodology to design an interactive simulation game, useful to teach discrete event simulation for undergraduate courses. The main objective of the game is to create an environment to make easier the students' understanding about simulation, such that they may learn the benefits of using simulation as modeling and analysis tool, and they may receive training on decision making concepts.

1 INTRODUCTION

Currently, due the constraints of the number of hours in a section and the contents to be covered, lecturing a Discrete Event Simulation course for undergraduate level implies some challenges for the instructors. These challenges implies taking several decisions from the design of the course to the selection of the didactic strategy to be used in each lecture. Many questions need to be answered long time before the first lecture, some of them are How lecturing simulation modeling, either using spreadsheets or a particular simulation software? Which simulation software selects to lecture the course? How much time to spend training the students in a particular simulation software? How much time to spend in lecturing basic concepts of discrete event simulation such as randomness, random variables etc.? and so on. Sometimes the instructor has not enough time to show real life applications of simulation or proving the advantages of the tool, thus the students experience is limited to a few small exercises (De Vin and Jägstam 2001).

On the other hand, the use of games in a lecture make easier the understanding of simulation concepts, since the students have interaction with real problems through a simulation model. Moreover, games can be designed to show the impact of changing the value of the decision variables, similar to a decision support system software (Kleijnen 2005). Considering this fact, this paper presents a methodology to design an interactive simulation game, useful to teach discrete event simulation for undergraduate courses. The main objective of this game is to create an environment to make easier the students' understanding about simulation, such that they may learn the benefits of using simulation as a modeling and analysis tool. Additionally, taking advantage of the game results, they may receive training on decision making concepts, which allows to explore the application of simulation as decision support system tool.

2 GAME CONCEPTUALIZATION

There are several ways to use computers in the implementation of didactic strategies in a lecture. One of these ways is employing packages or programming languages to perform the calculations required in the lecture. A different approach is using a general purpose software as an analysis tool, such that the students understand the relationships among variables and solve problems through building a model. Combining this two approaches a general purpose software package may be used as platform and interface, while a special purpose software may run behind to perform specific tasks in the lecture (Rao et al. 1998).

Considering this integrated approach, the game design is based on the following three statements.

- The learning process is considered as a knowledge improvement process
- The easier the interaction between students and software, the lower the rejection to play the game.
- The game should not require previous simulation expertise to be used as decision making tool.

2.1 Knowledge Improvement Process

Simulation may be used to support the continuous improvement process since allows conducting process assessment, documentation, and measurement of the impact of the proposed improvements, and additionally provides an environment to train the students as decision makers (Adams et al. 1999). On the other hand, considering the learning process as an improvement process, there are frameworks, models, and methodologies from other knowledge fields, which may be used to design the game. One of these models is the Crosby's maturity grid, which is used to quality improvements. Also, this model has inspired other models such as the Capability Maturity Model Integration or CMMI (Gack and Robinson 2003). Crosby defines five successive stages of quality maturity: uncertainty, awakening, enlightenment, wisdom, and certainty. In the uncertainty stage, management do not recognize quality as a management tool. The intermediate stages are focus on increase the management understanding and attitude towards quality. In the certainty stage management considers quality as an essential part of the improvement company system. (Calingo 1996).

Analogically to the Crosby's maturity grid the simulation game considers five successive stages or scenarios. Figure 1 shows the scope of each stage.

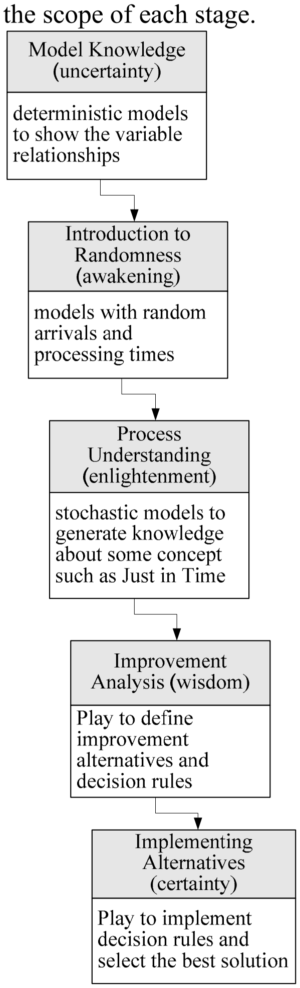

Figure 1: Sequential learning improvement through the simulation game

2.1.1 Stage I: Model Knowledge

In the first stage the undergraduate students may make comparisons among the results obtained from the simulation and analytical methods. At the end of this stages the students may be capable to draw a flow diagram of the model and identify the relationship among the variables in the model. For new situations, basic, simple models are a good way to start the learning process. They demonstrate quick results to participants, showing that there is much more potential for improvement than imagined (Adams et al. 1999). Thus, the main objective of this stage is learning about the relationship among the decision variables such as arrival time, processing time, inventory levels, or work in process. This objective is achieved through playing with the simulation model.

2.1.2 Stage II: Introduction to Randomness

The objective in the second stage is introducing the randomness concept, such that the students may compare the results obtained from the previous stage with the obtained from a systems which includes random variables. The game in this stage includes cost, sale price, and profit variables. These variables are useful to make comparisons among future improvements. Thus, the instructor may apply basic statistical analysis tools such as confidence intervals, percentiles, and average runs to explain relevant simulation concepts. Some examples of these concepts are the stop criteria either by time or a specific system condition, the steady state graph for a variable, and the implications of a decision based on steady state results against no steady results.

This stage finish the game induction for the students, thereafter, the game is designed to apply simulation as analysis tool and decision support system. Since the making decision process implies all the phases or steps needed by a decision maker to making the decision, Forgionne (1999) defines the following steps: Recognizing the problem to model, identifying the main objective and sub objectives, establishing the analysis and selection criteria, gathering data, generation of feasible alternatives, analysis and evaluation of the alternatives, and finally selection of on alternative for implementation. These steps are covered in the next stages.

2.1.3 Stage III: Process Understanding

Once the randomness concepts is learned, the students are ready to go deeper in the knowledge of a more complex system. Some possible goals of the game in this stage are meeting the demand of a product in the minimum time, meeting the production requirements at the minimum cost or get the biggest possible profit under some constraints.

Challenges like these caught the attention of the students and create an interactive learning environment. Also in this stage, the students may learn to perform a what if analysis, which is useful to introduce specific process concepts such as bottleneck analysis, just in time performance, impact of product defects, machine down times, the bullwhip effect etc. At the end of this stage the students may understand the relationship among the decision variables in the simulated system, such that the decision making steps of recognizing the problem modeled, and identifying the main objective and sub objectives are meet.

2.1.4 Stage IV: Improvement Analysis

The stage four is designed to provide a decision making environment for the students. Additionally to the elements included in the previous stages, the simulation model used in this stage represents an inefficient system, which is a rich environment to develop skills in the students. Due these system inefficiencies, the instructor has the opportunity to teach the students how to implement improvement strategies using simulation. Lecturing strategies to deploy the analysis and alternatives selection criteria, gathering data, and the generation of feasible alternatives. Moreover, the game may include constraints such as budget allocation, number of changes allowed, avoid to buy a new machine etc. At the end of this stage, the students may be able to analyze, and document assessment opportunities in the system.

2.1.5 Stage V: Implementing Alternatives

The model used in this stage is the closest to a real problem, the simulation game may include not only random variables on arrivals, processing times, transportation times, or any other element included in the previous stages but may include machine down times, rework, scrap, inventories capacities, the respective cost for each of these events and constraints, and so on. This final model is designed to prove the analysis and decision criteria defined in the previous stage, such that the students can carry out an analysis and evaluation of the improvement alternatives and finally select the best one for implementation. Such that, the results may be presented in terms of money, time to complete an order, performance indicators etc., thus the students may be able to make comparisons among alternatives. At the end of this stage the students will be pass through all the steps needed by a decision maker to making the decision defined by Forgionne (1999).

Additionally, once the students complete the five levels of the game, they indirectly may learn to identify some of the advantage of using simulation as analysis and decision support tool. According to Habchi and Berchet (2003) some of these advantage are:

- Realistic models are possible and may include any complex interactions between decision variables
- Improvement alternatives may be evaluated without direct system experimentation through what if analysis
- Simulation models and results helps decision makers to develop skills on making decisions through training and process knowledge.
- Discrete event simulation models do not require complex mathematics formulation

2.2 Interface design

The second statement considered for the game design is related to provide a handy user interface, such that the risk of rejection by the student may decrease. Previous research has shown that as the technology is easier to use, there is less rejection to use it (Workman 2005). Actually, one of the challenges to use discrete event simulation modeling as decision support system are that many people do not know how to program a simulation code, they are not willing to spent time learning a programming code, or they adopt a skeptical attitude to the benefits of the simulation, such that will be easier for the users to reject the software instead of used (Centeno and Carrillo 2001).

Considering this fact, the game interface runs over a spreadsheet, which is a common general software used generally in undergraduate courses such as production, finance, accounting, and so on (Rao et al. 1998). Also, the interface pay attention to usability concepts. For the visual interface design criteria, several sources were consulted, including the general interface design methodology proposed by Brown (1989). For each one of interface windows the game incorporates the following usability elements as the most important for a didactic user interface:

- Interface objects Organization.
- Color set for interface windows.
- Font set for interface windows.
- Verification and Control for object activation

The interface object organization follows the first eye glance trajectory, which is shown in the Figure 2. The users reads and captures the information from a screen the same way they do it from a magazine, which in western culture is done from the upper left corner to the lower right corner

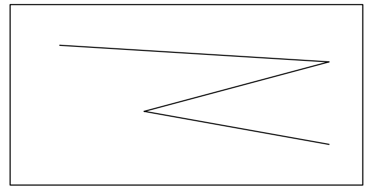

Figure 2: First eye glance trajectory

Regarding the color set, the information shown in the interface must to be clear for the students, therefore the color of these must to contrast with the window interface background. The font set is defined such that the students can see all the input information in one page. For verification and control the spreadsheets are protected. Also, all the input cells have activated the data validation option, this command allows to include an input message specifying the valid input data, such as integer values, decimal values, time, money, and so on. In case a student type invalid data an error alert remarks this fact indicating the type of data expected.

2.3 Systems Integration

Since modeling a complex system is not an easy task using spreadsheets, the game take advantage of the ActiveX automation available in some simulation packages. This automation is programmed using Visual Basic for Applications (VBA). VBA allows sharing data among the spreadsheet and the specific simulation package. This arrangement facilitate the interaction of the student with the simulation software, eliminating the requirement of knowing the programming language. Figure 3 shows the game software integration.

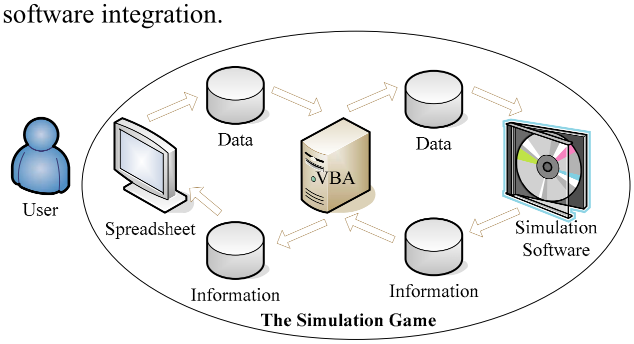

Figure 3: Game software integration

Initially, the user only interacts with the spreadsheet. Once the input data is complete, the VBA code takes the data and send it to the simulation software. The simulation software runs and generate the default information in a report file. The VBA code reads the information and select that one which is relevant for the decision maker. Finally the information is send to the spreadsheet and presented in a easy way to be understood by the user, such that the user may perform an analysis of the process, identifying opportunities, and making decisions about how to improve the process.

3 IMPLEMENTATION PROCESS

The suggested implementation process implies previous work for the instructor. The game structure provide a rich environment to apply problem based learning or case based learning strategies. Previously to use the game in a lecture, the instructor should to define the objectives and concepts related to simulation and decision support systems involved in the game. After that, the instructor designs and builds the game selecting a specific process, such as a line of production, a department with several processes, a floor shop, and so on. The simulation model should to consider the concepts and the successive learning stages discussed previously. Once the game is finished, the following step is design a case or a problem to be solve by the students, which focus the students efforts on learning the objective and concepts of simulation and decision support systems selected. Once the case or problem is done, the instructor provide a basic training about how to use the game in a lecture. After that the game becomes a course assignment, the students record all the changes made and the results obtained from these changes. They deliver an executive report about their findings and knowledge acquired after playing the game several times. Finally the instructor complies and resume all the findings and share them with the students in a feedback lecture.

4 MODEL VALIDATION

The first version of the model discussed in this paper was applied to twenty seven student taking a discrete system simulation course. All the students belong to the Bachelor in Industrial and Systems Engineering in the Tecnologico de Monterrey, Campus Monterrey. Generally the student take this simulation course during the last year of their academic program, such that some of them have job experince.

Regarding the development of the simulation model, this was build using ProModel. The spreadsheet used was Excel. ProModel and Excel can interact turn on the Activex software included in the ProModel installation. The simulation model was based on a production line, which may manufacturing three different products. Figure 4 shows the simulation model.

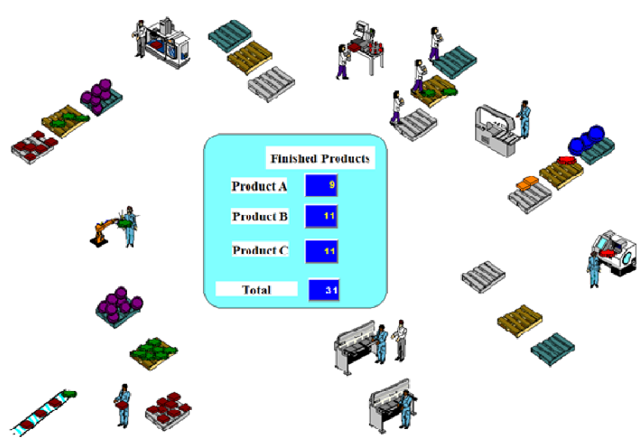

Figure 4: Simulation Model of a Production Line

The game objective was teaching simulation as a decision support system tool. To reach this objective students play the game in groups of at least three and no more than four. The game stages were designed using the description previously discussed. The stage one all the inputs, such as arrival times and processing times are constant. The final stage includes cost, several probability distributions related to arrival and processing times, defects, reworks, and down times among other variables.

The student spend three weeks playing the game, at the end of each week they summit a report, which contains their main findings and learning by student, and some group conclusions. At the end of these three weeks the students answer a survey based on their experience playing the simulation game. This survey contains the three following open-end questions:

- Do you consider simulation may be used as decision support system? Yes/No/Why?
- Regarding the increase of the difficult level in each stage of the game, Which benefits provide this arrangement concerning your making decision skills?
- Which is your main learning after playing the game.

Due the type of questions, the answers were different in terms of number of reasons and extension. However the 100% of the students recognized that simulation may be used as decision support tool. Some of the reasons mentioned by the students are: they can see what is happen in the system through the software animation interface, they can perform what if analysis, they can see the results of making a particular decision, such that it is possible evaluate the impact of the decision. Simulation provides statistical data, which can be analyzed to improve the system.

Regarding the increase of difficult in the game, the most of them recognize the last stage as the more closer to a real problem. Some answers remarks the relevance of knowing the system under analysis and recommend introduce other variables such as raw materials, transportation equipment, assembles, and so on. Also, some of the students mentioned, they found the opportunity to apply several analysis and improvement concepts from other courses taken in their curricula.

Concerning the last question, the answers provide by the students remark the relevance of the statistical analysis, the importance of a good model, and the value of some tool to generate information, which, makes easier the decision making process.

5 FUTURE WORK

Similarly to all product development, this game should be improved considering the comments and observation record during the validation process. The information collected from the students will be useful to make all the changes required to provide a game free of misunderstandings and able to meet the learning objectives of a discrete event simulation course. Further, this type of games may be introduced to other courses such as production management, Inventory management, or logistics.

On the other hand, there is a possibility to explore and develop several applications of this kind of games in the lecturing of different topics such as technological groups, lean concepts, logistics problems, product distribution, picking and packing problems, and all the problems where simulation has shown be useful.

6 SUMMARY

Teaching discrete event simulation requires any help to facilitate the use of computers in the course, such that the instructor may take advantage of the technology developed in the computer and simulation fields. Thus the instructor can teach the most relevant concepts of simulation during the short time available for lecturing in a term. Including games in a course is a very attractive way to reach this goal. Moreover, simulation is a tool which facilitates build a game, such that the students may learn by themselves through a case of study or a problem based learning assignment. The challenge of spent much time teaching a specific simulation package during the term is avoid due the spreadsheet interface, which is a more common general software, such that reduce the possibility of be rejected by the students.

A Case of study or the assignment may be designed to teach concepts from other field areas than simulation such as production systems, decision support systems, or demand management. The implementation of the a prototype with a small group of students, will provide the validation and verification required to improve the game and get the better results from its application, regarding the simulation and decision support systems learning objectives selected. The development of this kind of aids will provide a set of tools useful for other courses than simulation due the capability of simulation to model complex systems. Considering all the possible applications to this kind of games, simulation will be enhanced as a decision support system tool.

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