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Integrated Framework to Optimise Decisions: Supply Chain Serious Game (AUSUM)

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Abstract

Supply chain (SC) management challenges impose high pressure on the firm experts to explore innovative techniques to achieve better understanding of the impact of decisions on SC network performance. High complexity and dynamism of SC reflect on the limitations of traditional learning methods. Serious games have recently been identified as a potential learning approach for complex systems. This paper aims to develop an integrated simulation-based serious game (AUSUM) which incorporates optimisation techniques in an attempt to minimise risks and deliver better learning experience. The proposed game can be used for training and education purposes.

Keywords: Supply Chain Simulation-Based Serious Games, Decision Support Systems, Optimisation

Introduction

Improving your supply chain performance is as a challenge because of the fact that uncertainty, complexity and variability are common features of the process (Tang & Nurmaya Musa, 2011).Participants of the management and operations of the SC play a crucial role in any improvement programme. Lack of understanding of the management concepts of the supply chain could lead to a failure of the improvement plan. Leveraging the knowledge level of the field specialists requires exploiting novel and effective techniques (Korhonen et al., 2007). Simulation-based serious games have been recently used widely as training and learning tool (Léger et al., 2011). Gaming environment provides the learners with immersion and enjoying aspects (Ma, 2011). The excitement, competition and communication provided with games encourage the player to spend more time using the tool and gain better knowledge and hence learn new dimension of the process. Combining simulation with the gaming features seem to be

effective in helping to immerse the users in an environment that mimics the real system using simulation model engine (Peixoto et al., 2011).

On the educational level, lecturers strive to adopt effective methods in teaching operations management. New inspiring methods that can help in clarifying and delivering basic knowledge in an interesting engaging way. Decisions related to determining orders quantities, resource allocation and inventory management are critical in day to day business and potential graduates have to gain a thorough understanding on their impact on SC performance. New learning techniques and tools have been proposed as helping aids to achieve higher level of students' knowledge gain and retention. Serious games integrating simulation provide a potential approach that enables students to experiment on real life scenarios and examine impact of decisions in a more exciting learning environment(D-J van der Zee & Slomp, 2009)(Le Bars & Le Grusse, 2008). Operations management had a valuable share of gaming adoption in classrooms as a pedagogical supplementing method for the recent years (Lainema & Hilmola, 2005) (Chwif et al., 2003)(Villalta et al., 2011).

This paper presents an Automobile Supply Chain Management game (AUSUM). AUSUM is a web-based simulation game that simulates a full automobile supply chain that includes suppliers, manufacturers, distribution centres, and retailers. It simulates the decision-making situations related to placing orders, orders fulfilment, inventory management and various supply chain management operations. AUSUM is developed primarily to improving the learning environment and knowledge enhancement however it can also be used for research and training purposes. Game-based training depends on the intersection between three fields; learning, simulation and games (Maciuszek et al., 2012). Simulation tools tempt to mimic the real system behaviour with constraints (Sauvé et al., 2005). The key research question is how to develop a training/education framework that can be used in evaluating risks and support decisions. In order to answer this question, the research has set objectives such as: investigate the current practices of serious gaming in training, exploit the integration of simulation and optimisation in supply chain risk problems, and examine the validity of using serious gaming environment to improve learning and increase decision making skills.

Goal focused, competition and challenging aspects qualify games to be employed as an enjoyable helping aid in teaching courses (Pasin & Giroux, 2011)(Van Houten et al., 2005). Simulation-based serious games improve learning ability by providing an environment that mimics the real life system with full control on the decision variables and interesting response variable through the interactive interface (Durk-Jouke van der Zee et al., 2012). It increases the space for the learner to think without limits and experiment without pain or damage (Tobail et al., 2010). Reducing limits and fear of damage during in the learning process leads to better understanding of the complex concepts and theory which is extremely needed in many complex fields like supply chain management [using games in Supply chain]. Beer Game was the first production and logistics game which offered by Massachusetts Institute of Technology (MIT) in the 1960s. It started as a board game then brought to a computerised stage (Strozzi et al., 2007). They addressed the decision making variables and their effects. Other web-based games were developed to be used for learning and research purposes (Van Houten et al., 2005) (Dempsey et al., 2002). AUSUM game is developed to achieve the following objectives:
- Improve students' capabilities of examining different configurations and scenarios and hence enhance knowledge of system management.

- Provide instructors with a user-friendly configurable environment to integrate, track and accomplish learning objectives.
- Build a flexible environment to use in research and fulfil industry requirements.
- To examine and emphasis collaboration and cooperation concepts in supply chain management.
- Enhance the learning experience of students - learn by doing in an enjoyable environment.

A workshop ran to measure the effect of using simulation-based serious games in improving the knowledge level of the participants. The workshop objective is to examine the participant's appetite to the gaming approach and get feedback on the current version of the product. During the pilot session, Decision making issues were raised to highlight the benefits of using the role game as decision making support. Collaboration and communication skills were facilitated between participants during the playing time of the game in order to achieve better performance.

Design and implementation

The core of the system based on client-server technology as shown in (Figure 1). The client application represents the player and the administrator. A full simulation engine is embedded in the server to simulate the flows of information, material and capital streams through the different game roles (manufacturer, distribution centre, and retailer). In order to improve the communication between the client and the server, a high level syntax protocol is designed to broaden the communication spectrum. HTTP (Hyper-Text Transfer Protocol) is used as a wrapper for the transmitted message between the client and the server.
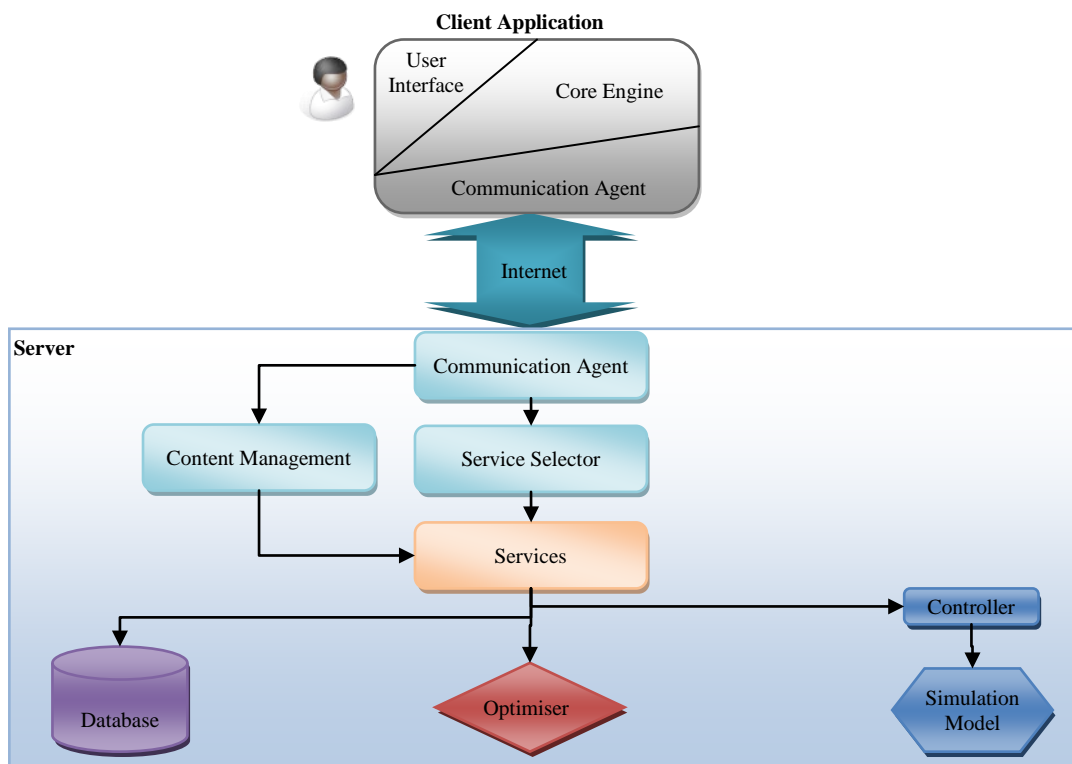

Figure 1 – Client - Server Framework Design

A user-friendly graphical interface receives the actions from the client and passes them to the core engine to encode them and manage the transmission issues. On the other hand, the server receives these messages from the client application to decode it and activate the service selector to enable the targeted service. A set of rules which is stored in the system database, controls the server response by applying penalties and rewards on the user's actions. If the player succeeded to fulfil an order on time, the reward points will be applied, on the contrary if fulfilling the order is delayed the opposite rule (penalty points) will be applied. It creates a challenging environment when applying such rules. Learning takes place when the student applies a decision and examines its effect on the supply chain network. Every ordering action made by the player is monitored by the server and stored to the cases database. The optimiser main role is to provide the server with optimum solutions for the stored ordering cases to be sent by the server to the player.

Client Role:

The client part of the system is an application running on the player machine to act as an interface between the client and the server. This part mimics the user's (Manufacturer's, Distribution Centre's or Retailer's) roles. It enables the client to apply the supply chain main functions such as generating demand, dealing with orders, warehousing goods and processing updates to materials and capital streams in a user friendly manner. Real-time fashion of the system enables the student to intervene to the simulation model running on the server and get the response in a reasonable time frame. Very smart displaying features are dedicated to transfer the server response to the client in an attractive and descent preview in order to ease the changes tracking and following the response of the simulation model (Figure 2).
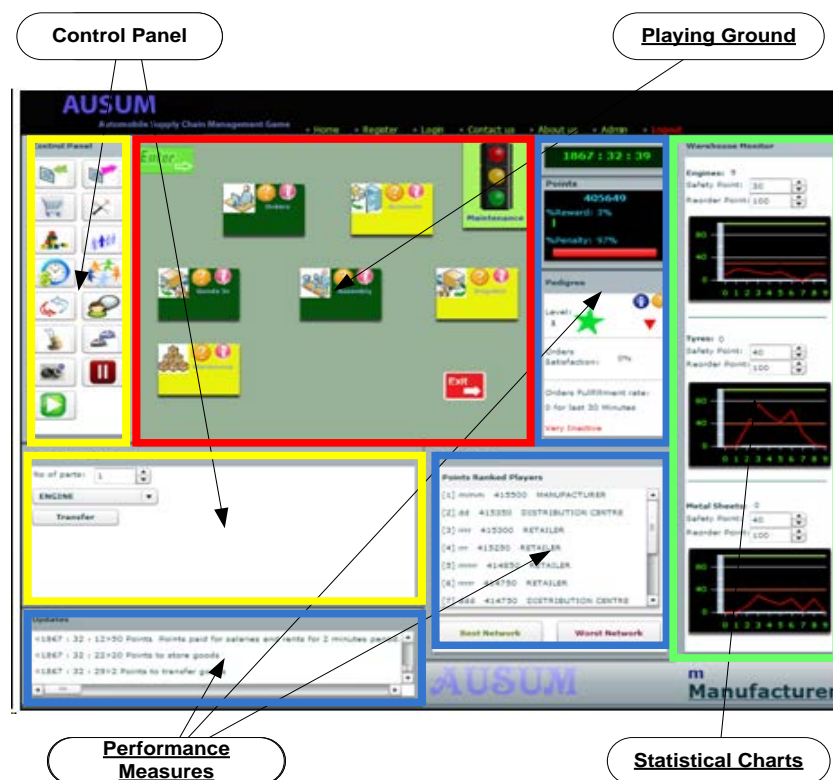

Figure 2 - The Client Interface

High level of usability is realised in a reach control panel to enable the player to choose from different actions such as building partnership with other players, displaying the player's network, placing and receiving orders, communicating with other players, applying for loans and doing maintenance for the assets. All users are synchronised into a 'global game time', and their status, levels and performance points are displayed in the status panel. The warehousing function charts and monitor enhance the user's awareness of historical and current stock levels, enabling them to set and manage warehouse safe and reorder points. A constantly updated statistics panel keeps users informed about their supply chain network performance, their ranking against other 'players', and the best and worst supply chain networks in the system. Cooperation and collaboration decisions between users are made easier by allowing the player to preview the other users' performance and ranking information.

As described previously, the communication between the client and the server is handled by a high level syntax communication protocol based on the message unit which is depicted in (Figure 3). Every message consists of five sections; (i) IDENTITY to define the user and the session identification number, (ii) BROADCAST section defines the users who will be affected by the result of the action produced from the message execution on the server, (iii) OPTIONS part of the message is concerned about executing pre or post functions in relation to the message execution, (iv) FUNCTIONS is the main part of the message which contains one or more functions to be executed on the server, and (v) PARAMETERS is the last part which holds the parameters for the functions.

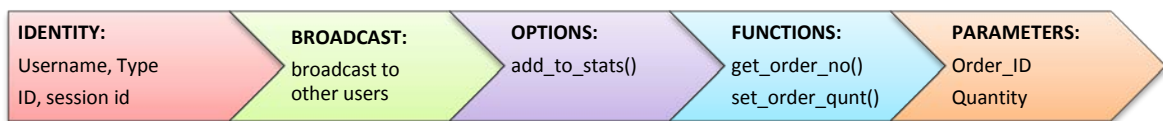| IDENTITY:	BROADCAST:	OPTIONS:	FUNCTIONS:	PARAMETERS:
Username, Type ID, session id	broadcast to other users	add_to_stats()	get_order_no() set_order_qunt()	Order_ID Quantity

Figure 3 - Communication Message Structure

Administrator Role:
The administrator role basic functions are to configure the simulation variables, create scenarios and follow up the users' results and performance (Figure 4). A web-based client application is built to handle the administrator role. System configuration tab gives the administrator the capability to set demand patterns to the whole supply chain network, control the suppliers' behaviour and delays, and initialising the logistics network performance and parameters in addition to enabling or disabling the optimiser engine. There are to modes to configure the system variables; randomly to realise the concept of variability and uncertainty in the system or through predetermined values. Tracking the players' performance is updated regularly and displayed for the administrator in interactive display components. Historical data is collected after every game run to indicate the performance of the users and the level of the learning gained by the game. Charts and tables are used to display the historical data and statistics about the players' performance which is prepared by the server and sent to the administrator application. Similar core engine to the player application is used in the administrator application to handle the communication between the administrator application and the server.

Figure 4 - The Administrator Interface

Server Structure:

The server is composed of different components working together to enable login and communications with the system's users, controlling the simulation model, managing database, and integrate the optimiser (Figure 5). All the aforementioned components are synchronised to the global system time.

Communication agent - handles the received and transmitted messages between the server and the client's different types (players or administrator). It works as a decoder to decode the received messages and send the required function and parameters to the service selector. Sending back the server response to the client involves the communication agent to encode the message and manage the transmission issues.

Service selector - selects and activates the required service with the current parameters, supervises the execution process and enables the other required parts of the server to guarantee full execution for the service.

Content manager – it works at the beginning of the communication with the client where the identity of the user is sent to the server and according to this identity and the type either player or administrator, a set of services and levels of security are enabled or disabled.

Database manager - it keeps the players' records, identity and sessions saved and updated. It also handles all the configuration parameters to recover any communication disconnection between the server and the clients.

Simulation model - A full simulation model is running as a part of the server to simulate the flow of goods, information and capital between the different client roles (Supplier, Manufacturer, Distribution Centre, and Retailer). Controlling the model variables and receiving the results is controlled by the model controller which acts as an interface between the model and the server's other core components.

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Optimiser - A genetic algorithm–based optimisation engine has been embedded in the server core engine to serve the simulation model in finding the optimum order quantity. Every time the player places an order, the case is captured by the server and the problem is applied to the optimiser to calculate the optimum order quantity. There are two modes for the optimiser; the first one when the optimiser is enabled by the administrator then the player can see the solution obtained by the optimiser and compare it to his/her decision to get learned while the second mode when the optimiser is hidden and only the administrator who can track and assess the students' behaviour. Demand stream and lead-time stream are stored regularly in the system database to be ready to feed the demand forecaster and the lead-time forecaster. Inventory holding cost minimisation is the objective function of the optimiser. Order quantity is generated from the optimiser and sent to the client application to help the user in the decision-making process (Figure 5).
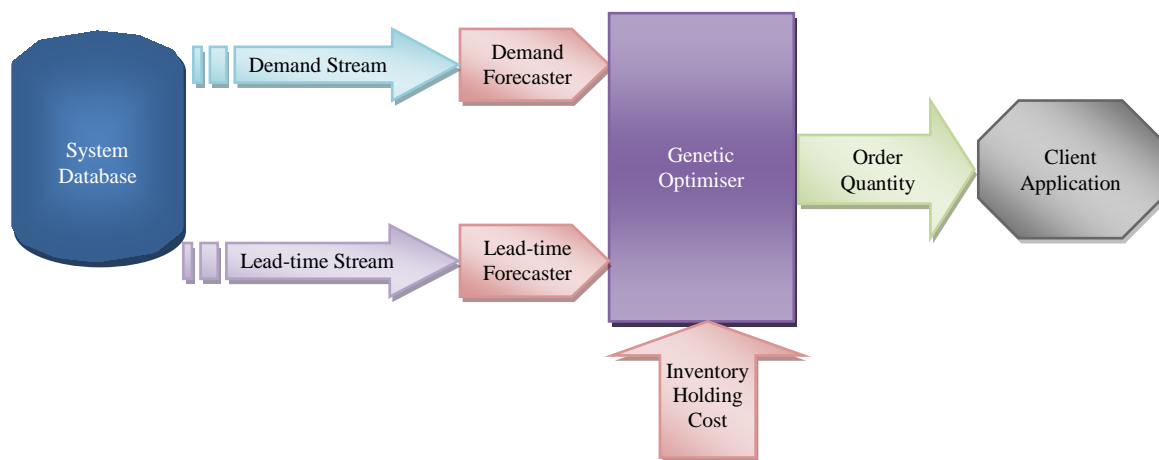

Figure 5 - Genetic Optimiser Main Structure

Experiments and Results Analysis

AUSUM was piloted in supply chain module in the Logistics and Supply Chain Managements Programme at College of Business - Dublin Institute of Technology (DIT). Sixteen students were involved in the pilot study to evaluate the game to be used in the classroom and as a learning tool. Students were divided into three groups; manufacturers, distribution centres, and retailers. The pilot experiment session started by introducing the game to students and giving them a short tutorial regarding playing instructions. The game configurations such as demand patterns, suppliers' variables and the logistics' controlling parameters are set by the administrator. Each student played as a part of the supply chain network by managing his/her role's company. After the end of the playing, students filled an anonymous survey to evaluate the game. A Likert five-point scale questionnaire ranging from "Strongly Agree" to "Strongly Disagree" was applied. It was mainly consisted from two parts; usability of the game and the learning ability. Table 1 reviews the student's evaluation to the game interface and utilisation and Table 2 shows students' responses to the learning effect of the game.

Mean scores were close to or greater than 4 which can be translated as general agreement from student side to the interface of the game (Table 1). The mean values are also in the range of agreement and strongly agreement which indicates a general satisfaction about the game effect in learning (Table 2). Combining the previous two tables together in (Figure 6) provides a general indication about students' acceptance for the game.

*Table 1: Students' evaluation for game interface and utilisation.*

Question	No. Of Strongly Disagree (Value 1)	No. Of Disagree (Value 2)	No. Of Neutral (Value 3)	No. Of Agree (Value 4)	No. Of Strongly Agree (Value 5)	Mean	STD
The game was helpful in the decision-making process	1	1	2	10	2	3.688	1
The game realises the concepts of co-operation and collaboration in supply chain	0	1	2	4	9	4.313	1.016
Helps in improving supply chain learning	0	1	4	8	3	3.813	0.81
Highlighted the communication between the role functions.	0	2	1	8	5	4	0.944
Emphasises the controlling variables of the supply chain performance.	1	1	1	7	6	4	1.125
Do you think this game is better in delivering Supply chain management concepts than the traditional lecturing?	0	0	2	1	13	4.688	1.061

Table 2: Students' evaluation for learning aspect of the game.

Question	No. Of Strongly Disagree (Value 1)	No. Of Disagree (Value 2)	No. Of Neutral (Value 3)	No. Of Agree (Value 4)	No. Of Strongly Agree (Value 5)	Mean	STD
The game is an enjoyable way of learning	1	2	1	6	6	3.875	1.218
The game facilities helped in playing an effective role and following the network improvements	0	2	0	8	6	4.125	0.96
The rule of game is clear	1	0	6	7	2	3.563	0.984
Interface design is good and highly usable	0	1	4	6	5	3.938	0.901
The interface is user-friendly	1	0	1	10	4	4	0.944
Are you interested in playing it for more sessions?	0	0	2	0	14	4.75	1.097

Students' feedback comments were in summary:

- Animation is interesting to help us understanding the movements of supply chain parts and ease learning
- Being mindful of the three areas (manufacturer, retailer, and supplier).
- Better if there is a visual layer to show the warehouse capacity
- Enjoyable way of learning
- Learned new supply chain concepts like ordering, lead-time, stock level and replenishment.
- Graphs of the whole network makes it easier to understand the whole supply chain relations
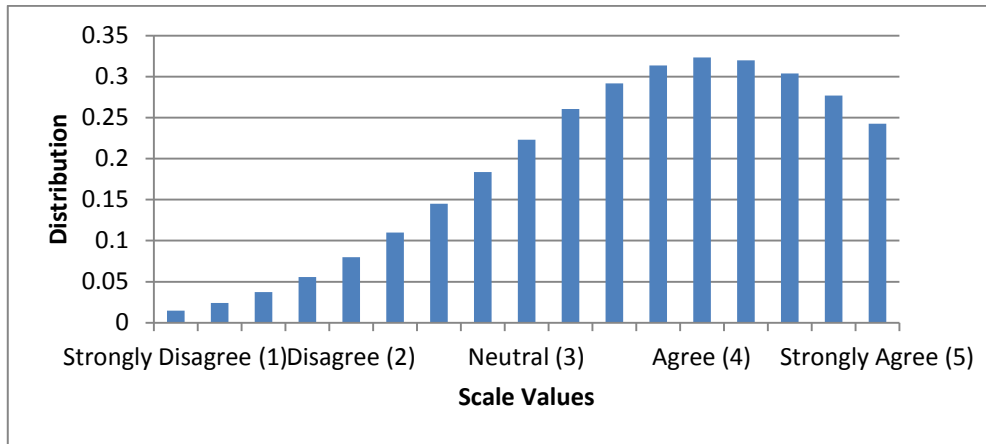
Figure 6 - Students' Survey Statistical Analysis

Students were very motivated to play the game and discuss the operations of the game together. They were interested in playing the game for more sessions. It is believed that they gained more ground regarding the impact of decisions on supply chain performance. Interesting comments about technical aspects of the game such as animation and interfacing are useful to the developers.

Conclusion

Given the current challenging market, supply chains networks are under immense pressure to deliver and make the right decisions. New methods to develop better understanding of the SC dynamics and risks of decisions are always welcomed by experts in the domain. Research reported the benefits of using modelling and simulation approaches in Supply Chain Management (SCM); however reports indicated the lack of learning enablers in these approaches. Engaging supply chain trainees and potential graduates in a knowledge enhancement process is a key to improve the supply chain performance. High complexity and dynamism of supply chain management are obstacles that traditional training techniques failed to address.

Serious games are considered to be a potential learning approach that attracts younger generations. The use of simulation in manufacturing was well acknowledged by industry and in particular in forecasting and verification of new strategies. Integrating gaming environments has enabled us to create an inspiring yet engaging thinking approach by challenging the players. This environment is found to leverage the learning ability and encourage knowledge retention.

The aim of this paper is to present the design, development and pilot the implementation of a new integrated simulation-based serious game (AUSUM). This game incorporates optimisation techniques that can be used to minimise risks due to decisions. Optimisation wizard indicates the potential risks and supports the users at the critical decision points. This in return will enable the learning to take place by justifying the optimum decision at every stage. To make the optimiser more efficient, it has been designed to work in real time fashion to cope with the dynamism experienced by the active game playing. The proposed framework of AUSUM Game can be used for training and education purposes.

Results of the pilot study show the appetite and advantages of using serious gaming environment in understanding potential risks. Integrating optimisation with simulation in real-time has significantly improved the learners' experience and supported the rational of critical decisions. It is believed that the proposed framework can contribute positively to the

knowledge domain. AUSUM interface and structure has gained a satisfactory level from students. Results from the survey showed a trend toward the "agree" and "strongly agree" positions of the Likert scale. Further experiments on different disciplines are ongoing and to be published soon.

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