SERIOUS GAMING AND BUSINESS APPLICATIONS: A WEB FRAMEWORK BASED ON SYSTEM DYNAMICS.

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Abstract

In this work we present the construction, empirical validation and experimental application of a web based system for teaching topics of Business Administration. The same concepts can be easily extended to other formative areas. The system realizes a cooperative behavior of human agents (learners) who interactively take decisions for a simulated profit oriented enterprise. The technical design is based on System Dynamics and can be extended with the use of intelligent agents, acting as competitors.
The main purpose of the game is to transfer knowledge about the strategic management of a profit oriented enterprise. At the beginning of each simulated time period, certain core decisions must be made, and the effects of these strategies will be shown at the end of this period, in the form of typical accounting schemes and indexes. By playing with the system, but above all by sharing decisions and motivations within their group, the students will be able to learn the principles of strategic management and accounting in a “maieutical” way, i.e.: not just by studying on books, but also interacting with the systems and other colleagues.

Introduction

Serious gaming is a promising and interesting research field, proposing games with a primary purpose different than pure entertainment. The goal of a "game-learning", i.e. a subset of serious games, is that of teaching some subject and, in particular, to teach how to solve a particular problem or to face a given situation (Aldrich, 2009).
Business simulation games (Rollings and Adams, 2003), or economic simulation games, are serious games that focus on the management of economic processes (Rollings and Adams, 2006), usually in the form of a business. "Pure" business simulations have been described as construction and management simulations without a construction element, and can thus be called management simulations (Zyda, 2005). Indeed, micromanagement is often emphasized in these kinds of games. They are essentially numeric, but try to hold the player's attention by using creative graphics (Lang and Pueschel, 2009). The interest in these games lies in accurate simulation of real-world events using algorithms (Laramee, 2002), as well as the close tying of players' actions to expected or plausible consequences and outcomes (Slator et al., 2006). An important facet of economic simulations is the emergence of artificial systems, game-play and structures (Natkin, 2006).
Since these simulations usually simulate real-world systems, they can often be used for learning Economics and Management (Farkas,2007). Some benefits of simulations are that they permit students to experience and test particular situations, before facing them in real life (Schurr, 1994): they allow students to experiment and test hypotheses (Thole et al., 1997) so that subjects seem more "real" to them than when taught passively from the blackboard.
Another very important strength point of business games is that students can be organized in teams to face them. Collaborative learning is a situation in which two or more people learn or attempt to learn something together (Dillenbourg, 1999). More specifically, collaborative learning is based on the model that knowledge can be created within a population where members actively interact by sharing experiences and

take on asymmetry roles (Mitnik et al., 2009). Put differently, collaborative learning refers to methodologies and environments in which learners engage in a common task where each individual depends on and is accountable to each other. Collaborative learning is heavily rooted in Vygotsky's views that there exists an inherent social nature of learning which is shown through his theory of zone of proximal development (Lee and Smagorinsky, 2000). Often, collaborative learning is used as an umbrella term for a variety of approaches in education that involve joint intellectual effort by students or students and teachers (Smith and MacGregor, 1992). Thus, collaborative learning is commonly illustrated when groups of students work together to search for understanding, meaning, or solutions or to create an artifact or product of their learning.

The serious game presented in this work is a business game, based on the principles of system dynamics, involving collaborative behavior.

Forrester's System Dynamics (SD) is a commonly used systems modeling technique with a long tradition of applications to social systems (Forrester 1961; Forrester 1971; Roberts et al. 1983, Sterman, 2000).Systems Dynamics models consist of a set of difference equations (similar to differential equations, but with a fixed time step) that are recursively solved forward through time. In general, SD models consist of a relatively small number of state variables that completely define the state of the system being modeled, and a specification of the rate of change of each of the state variables, which depends on the previous system state. SD has its roots in dynamic systems and control theory, and emphasizes the importance of feedback effects between aggregate level system components as strong determinants of system behavior.

The mechanisms within the game are founded on difference equations, modeling each part of the simulation. In this way the system "resembles" a real one, where a given decision not only influences directly one or more aspects, but, indirectly, can affect many other variables.

Besides this business game is web based, meaning that anyone can access it from everywhere, without needing to download anything locally. For this purpose the project has been developed by using Java and its main instance is currently installed on a server of the e-Business L@B.

The design philosophy and Simon's conception

In his book "The sciences of the artificial", Herbert Simon (1996) defined design as "the sciences of the artificial and the architecture of complexity". Simon claims that "Everyone designs who devise courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state."

According to Habraken (1987), "First: there are always many designers. The artifact to be made is designed in a process of cooperation and negotiation among many factors. The participation designers have different expertise and their responsibilities in the larger design task can be distributed in many ways. Second: the artifact changes continuously. Human settlements are never finished and we keep designing them. Though each designer can finish his individual task, urban environments and also individual buildings continue to be designed upon throughout their lifetime."

Design is an act of seeing, thinking and making. As Simon indicates, to design a complicated artifact, one powerful technique is to discover viable ways of decomposing it into semi-independent components corresponding to its many functional parts." The design of each component can then be carried out with some degree of independence of the design of others, since each will affect the others largely through its function and independently of the details of the mechanisms that accomplish the function." Greg Costikyan, in his lecture Design for Serious Games, said "Games are systems, mutable and exploratory, demonstrate the complexity of the situation, show the constraints of different actors, inculcate rational problem-solving". He also argues, this system allow players to think about games as systems and designed spaces rather than simply moment-by-moment playable environments. In real life experience, we should pay great attention to the function and building code, to make the building really "work". This nearly

decomposable system can also be used in architectural design. Buildings are designed by many professional architects with quite different aesthetic sense and background. But games are usually defined as a “trial and error" process to gain certain property or overcome obstacle with much degree of freedom, which are not really related to the real life function. The key of design as a game is, through a game we can learn the design process and achieve the similar design goal.
For these reasons in the proposed framework we follow the Viable Systems Approach indicated in Golinelli (2010); the enterprise, as an economic complex system, is considered as an entity composed by many interacting levels. Besides, it interacts with the environment and with the stakeholders (e.g. customers, suppliers, and in general all the persons, groups, organizations or systems that affect or can be affected by an organization's actions.

The simulation framework

An existing simulation framework is described in this paragraph, used as a teaching support in some University courses at the Department of Computer Science, University of Turin, Italy; this will be the one to which the agent based paradigms described before will be applied, in order to obtain a virtual tutorship and a decision support system for the learners (the users). The simulation framework , has been conceived as a teaching platform, used for transmitting such concepts as “double-entry accounting”, and the way in which the decisions taken in a real enterprise affect the synthetic results, at the end of each period (month). The model, for now, is just in Italian, but a translation in English will soon be available.

In this model, the users have to take a number of core decisions at the beginning of every month; the system, based on Forrester’s System Dynamics, generates a set of reports, typical for Management and Enterprise analysis. The users, by reading these reports, can track down the influence of the single decision – or even better the aggregate effects coming from two or more decisions – on the synthetic results, representing the monthly performance of the whole enterprise

Agents can have many roles in such a system; first of all, reactive agents can be used as a part of the system, in order to simulate customers or suppliers. These agents should be very simple, just reacting to some market curve. On the other hand, reactive agents could also be the production implants, with the possibility of being programmed by the users in some way, and then adapting themselves to the number of pieces to be produced, and so on. This kind of interactivity would make the model more realistic.

Cognitive agents may have different and more important roles in this kind of models used for e-learning. After a training period on the model itself, using the reinforcement learning methods discussed above, an agent can compute some strategies to be used to make profit in the simulation. That said, this agent could then be used both as a decision support system for human users – since it could foresee some results, based on its acquired experience – and as a virtual tutor, explaining the relations among certain variables (decisions) and the achieved results. This could help the learners to understand the cause/effect links.

The Inner Structure of the Model

The model is built using a structure based on the theory of System Dynamics.

The model itself is considered as an artifact, an interface between the internal structure (implemented in Java) and the external environment, i.e.: the physical one, in which the system itself is used by the learners, i.e.: the final users of the model.

There are six main subsystems, mutually connected, in the simulated enterprise: production, finance, implants, research and development, marketing and sales. Some of these subsystems are divided into other subsystems, if needed (e.g.: national sales and sales to the rest of the World).

The model is a dynamic system and the temporal walkthrough in the system has been converted into a set of differential equations and laws that can generate the walkthrough itself. This description consists into a constant relation between the system status in a generic time T and the status after a brief time interval "delta T" (DT).

Two are the main variable types in the model: the stock type and the flow type (or rate). The latters are used to recalculate the formers after each DT.

		(Range)
Lotto di acquisto materie prime (C)	150.00	(0 ~ 5000)
Lotto da mettere in produzione (C)	150.00	(0 ~ 5000)
Investimenti in impianti (euro)	32000.00	(0 ~ 500000
Investimenti in ricerca e sviluppo (euro)	400.00	(0 ~ 5000)
Assunzioni mano d'opera diretta (p)	1,00	(0 ~ 250)
Licenziamenti mano d'opera diretta (p)	1,00	(0 ~ 250)
Prezzo unitario mercato nazionale (euro/pf)	566.00	(7 ~ 700)
Durata media del credito concesso ai clienti nazionali (gg)	30.00	(30 ~ 360)
Interesse annuo concesso ai clienti nazionali (%)	10.00	(1 ~ 20)
Promozione mercato nazionale (euro)	32.00	(0 ~ 5000)
Prezzo unitario mercato estero (euro/pf)	1000.00	(10 ~ 1000)
Durata media del credito concesso ai clienti estero (gg)	30.00	(30 ~ 360)
Interesse annuo concesso ai clienti estero (%)	10.00	(1 ~ 20)
Promozione mercato estero (euro)	32.00	(0 ~ 5000)
Tempo o dilazione richiesta per i pagamenti di fornitori (gg)	30.00	(30 ~ 240)
Prestiti richiesti alle banche (euro)	1,00	(0 ~ 500000
Estinzione prestiti bancari (euro)	1,00	(0 ~ 500000

Figure 1: a form for monthly decisions

Many of these flows are generated by the "actions" of the learners, i.e.: their decisions, in order to modify the states of the system. Not all the stats are modified by external actions, though. There exist some inner actions and regulations that can be considered as "internal implicit decisions" performed by the system, used to normalize the levels. The choice of the configuration and balance among the external decisions and implicit decisions identifies the nature and type of knowledge that has to be transferred to the learner in a direct od indirect way.

The external decisions are those that make it possible for the individual learners to know the object of their studies, since the object is directly "acted upon" by them. This kind of actions are simply referred to as "decisions", since they can be carried on by the learners. The other kind of decisions are those that make it possible to keep the system "alive" even when the learners (for a lack of knowledge) has not been able to lead the system.

The enterprise is part of a bigger external environment (or space) with which it continuously interacts. This environment is configured by some other sub-systems, like the banking system (able to supply the financial means for the developing of new technologies, new products and the enterprise itself), the market system (where the demand is generated in the form of orders for the enterprise), the technology system (that determines what kinds of technologies are available at a certain time step), the suppliers system and customers system (respectively simulating those sides) and the workforce system (determining the average wages, the work supply on the market and so on).

The equations in the model are in the form of:

$$SFi = SSi + (RIi - ROì) * DT \qquad (1)$$

Where SFi at the first member is the i-th Stock Variable at the end of a DT, while the SSi on the right is the same variable at the beginning of the DT. RIi and ROi are respectively the Input Rate and Output Rate relative to the i- th stock variable (Bussolin, 1979).

The variation is then depicted as a difference among the Input Rate and Outup Rate during the considered DT; this is summed to the previous stock value, to calculate the new one. It's important to notice that the algebraic difference among the two rates is to be weighted by the time in which that rates applied.

The units of measurement in the system directly derive from the above equation. The time is measured in months and the stocks are measured in units. The rates are then units/month and DT is again measured in months.
DT is a very brief time period; for simplicity, in the model is set to be 1/100 of a month.

Conclusion and outlook

A web based framework of a business game has been presented in this work; the main purpose of this artifact is that of transmitting managerial and strategic concepts, at the basis of enterprise and business management. It belongs to the field of serious games and is based on the principles of System Dynamics and, hence, on systems of difference equations to rule the interactions of its inner parts.
The students facing this game should be organized in teams, thus creating a collaborative form of learning by doing; by taking strategic decisions at the beginning of each simulated period, the students exploit the results by receiving a prospect based on double entry accounting.
This framework has already been effectively employed in University classes and High School.
In future works, the framework will be complemented by intelligent agents (Remondino, 2003 and Remondino, 2004) acting as competitors and/or tutors for the human players. So, the agent based framework will constitute a form of virtual tutorship for the learners. The agents act as a decision support system for the decisions to be taken, and can explain some cause/effect relations. The agents themselves learn how the model work by practicing it, through some reinforcement learning techniques, and are then able to assist the learners in the decision process.

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