SERIOUS GAMING, MANAGEMENT AND LEARNING
An Agent Based Perspective

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Abstract: We present the construction 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, and used to transfer knowledge (learning by doing). The system realizes a cooperative behaviour of human agents (learners) who interactively take decisions for a simulated profit oriented enterprise. The technical design is based on System Dynamics and Artificial Agent modelling. An agent based framework is applied to the model in the form of virtual tutoring system for learners; the cognitive agents learn through a trial and error technique. After the trial period, they can be used as a decision support system for the human learners.

1 INTRODUCTION

Business Games (BG) can be considered role playing games, characterized by a managerial context. The players usually face some situations typical for enterprise management and must take various core decisions, mainly about marketing, logistics, production, research and development politics and so on. A very interesting feature of business games is that they can be employed as a teaching instrument and for training; the students/trainee can learn some important concepts about enterprise management, by trying them on the field, instead of just studying them on books. This is regarded as "learning by doing" concept. The main didactic goals for BGs are to refine the decision capacities of the learners when facing situations of uncertainty, and above all their ability to take managerial decisions when there is a trade-off between risk and profit. Besides, through a BG, some advanced managerial techniques can be reached, and so can be the interaction among the different enterprise functions.

The BG presented in this work is built on the System Dynamics methodology (Forrester, 1961) and following the specifications given in Bussolin (1979); this means that the mechanisms of the game are based on finite differences equations and curves defining the main parameters of the game itself.

The innovative part is constituted by an agent based framework applied in the form of virtual tutoring system for learners; the intelligent agents learn by trial and error, based on Reinforcement Learning paradigms, by practicing the system. After this trial period, they form a model of the cause/effect relations among the decisions and the observed results and can then be used as a decision support system for human learners, during the game.

2 MODEL STRUCTURE

The model is built using a structure based on the theory of System Dynamics. The model itself is considered as an *artifact* (Simon, 1996), i.e.: 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. 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

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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 latter are used to recalculate the former after each DT. 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 states are modified by external actions, though.

There exist some inner actions and regulations that act 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 or indirect way.

The external decisions are those that make it possible for the individual learners to know the object of their studies, since it 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, here seen as a complex system, is part of a bigger external environment with which it continuously interacts. This 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:

$$SFi = SSi + (RIi - ROi) * DT \quad (1)$$

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.

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

The units of measurement in the system 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 it's set to 1/100 of a month.

3 COGNITIVE AGENTS

Reactive agents don't own an internal representation of the environment and react to the stimuli coming from it, by retrieving wired behaviours similar to reflexes without maintaining any internal state.

Cognitive agents' behaviour, on the contrary, is goal-directed and reason-based; i.e. is "intentional".

Basing on the final goal, the agent chooses its action (or set of actions) according to its beliefs (knowledge) of the world. At a higher level, cognitive agents can choose a specific goal from a set of achievable ones. Cognitive agents' behaviour can be seen as a two steps process: 1) goal selection and 2) action selection to reach the selected goal.

The action selection problem at time *t+1*, along with the goal selection, at a macro level, are central topics, when the agents must learn how the models works, by experimenting on it and being able to act as a decision support system for human users.

So, in the following, by action selection we do not strictly mean the problem of choosing which action to take at a micro level (agent level), but also which one, among the possible goals, to select.

In order to decide which actions to perform, the utility for each of them must be evaluated; specific Reinforcement Learning (RL) algorithms are used, which transform quantitative data (the *payoff*) in behavioural patterns for the agents. An agent endowed with some RL algorithm, when in a particular state of the world (x), performs an action (a) and gets a payoff (r), calculated by a reward function based on the consequences of the action itself. Through a trial & error mechanism the agent learns what are the actions that maximize this numerical value and computes an internal table, linking actions to states. It's straightforward that in the presented model the macro-goals are multiple and typical of enterprise management (e.g.: maximizing the profit, improving the implants, expanding the research & development and so on).

Besides, the actions to be performed to achieve any of these goals are in the form on a vector, containing the decisions affecting each part of the enterprise and the relative strategies.

4 ENTERPRISE MANAGEMENT

The model supplies the user (and the agents) with a set of generated reports, typical of Management and enterprise analysis. The users, by reading and analyzing them, 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.

According to the traditional use of the above quoted modelling, the design of a whatever economic system being simulated provides a discussion of its results "at the end" of simulation, and the traditional transfer of knowledge suffer from the paradigm of "*coeteris paribus*" i.e. teaching is concerned with the behaviour of just given variables at a time, while keeping the remaining ones "still". On the contrary, in the presented approach, the learner (or better, the team of learners) "drives" the whole system by his own decisions during the decision making process, learns through the interaction and the process of "role playing" within the group, and at the end of each month gets a set of reports, that will constitute the basis for the decisions to be taken during the following one.

The users, by reading and analyzing them, have to 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.

While the model has been originally conceived as a teaching platform, in Universities and schools 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), it can be employed also as a simulator for managing purposes. After tuning it basing on a certain enterprise, it can be used as a what-if analysis tool, i.e.: a simulator in which certain changes can be done, in order to see how the system reacts to them, before doing them in the real world.

The cognitive agents can help both when the system is used as a teaching platform in schools, and when it's used as a real simulator. In fact, in the first case, the agents can correct the common mistakes of the students, by learning a correct policy (or, better, a correct set of action for a given managing strategy) and aid the students when they need to keep their decision. For an example, it's possible to think about a simulated enterprise, in which the R&D department is particularly weak, while the income is high, but the products are getting old and – possibly, will turn obsolete in few months. Unskilled students, that of course are not used to manage real enterprise, will probably get excited by the good and steady incomes, and will likely not invest in the R&D department. In few months, the competitors will have better products on the market and suddenly the enterprise will drastically diminish the sold quantities. Unfortunately, it will be too late to start an R&D campaign, since that'll likely require several months (or even year) to develop a new competitive product from scratch.

A cognitive agent, when turned on, by means of a dynamic hint could inform the students that their product is in the maturity phase of its life cycle, and that soon it'll face a probable decline. If, that notwithstanding, the students still do not invest in R&D, then the agent will suggest this as a possible strategy to prevent a forthcoming decline for the product, that will lead to a likely drastic reduction in the sales and will directly point to R&D as a way to overcome this in advance, by developing new products or improving the old ones.

When used a dynamic real-time simulator for what-if analysis, the agent has a different task; since we can aspect that users are, in this case, experienced managers, the agent could help them in finding the cause-effect relations basing on historical data. For example, when the system is tuned on a real enterprise, and empirically validated on its raw data, it could be used to conduct a scenario analysis. If we consider, for instance, the introduction of a new machinery in a manufacturing enterprise, then the system will keep track of its costs (variable and fixed) and all the interactions it could have with the rest of the environment (e.g.: required labour force, energy, training and so on).

Though, without an intelligent system acting as a supervisor, many of these relations will result in black boxes, exactly as it happens in the real world. An intelligent agent could supply step-by-step explanations for that, by monitoring all the data flow, through statistical and data-mining techniques. Besides acting as a decision support system for human learners experiencing with the model, artificial agents can be used to supervise the decision taken by learners, in order to interpret them in a cognitive way.

For example, in the previously mentioned enterprise accounting model, some users could immediately pursue an high profit, while others could be concerned first with the expansion of their enterprise on new markets. Others could choose to improve industrial plants, while others could want to differentiate production and invest on research & development and marketing. All these decisions are complex, since they are determined by the combination of many different variables.

Sometimes the learners won't even realize that they are pursuing a strategy instead of another one, and they often won't foresee what the selected strategy could bring.

5 REACTIVE AGENTS

The agents can also constitute some parts of the model itself (Remondino, 2003); in the considered enterprise accounting model, some reactive agents can form the supply chain, or the warehouses, or even the competitors operating on the same market.

When dealing with reactive agents, the action selection problem is to be found at a macro (aggregate) level, i.e.: population level. If reactive agents are the competitors of human learners in the simulated world, they could have a fixed rule of behaviour over time. Some evolutionary algorithms could be embedded in the agents, so that the best players on the market could merge, to form some other artificial players with an even better behaviour. In this way it's possible to start with a population of agents with a random behaviour, facing the standard decisions in the model, and select – through the various "generations" – the best ones.

So it's not the single agent that selects his behaviour by updating its own policy (that remains the same, being the agent a reactive one), but the population that evolves over time, through the mechanism of reproduction and mutation. This is an approach often used when the rules of the environment are given and the main task is to observe some emerging aggregate behaviour arising from simple entities, i.e.: reactive agents.

Since these agents does not feature a goal based – pro-active – behaviour, the way they act tends to be deeply dependent on the choices made by the designer. In order to design flexible systems, the aggregate behaviour (at population level, i.e.: macro level) can be made self-adaptive through the implementation of an evolutionary algorithm (EA). In this case the agents will have a wired random behaviour at the beginning, and evolve according to the environment in which they act, through a selection mechanism.

6 CONCLUSIONS

A cognitive business game has been presented in this paper, used to form learners in the Universities and schools. The structure of the model is built on the theory of System Dynamics. The inner structure of the model has been briefly described in the paper, along with the main sub-systems tied to form the whole. The users of the system must take decisions at each time step, after which the system calculates the corresponding results, showing them according to the principles of double-entry accounting. Cognitive agent based paradigms are then described as a development for the system itself. The agent based framework constitutes 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. A brief description about how reactive agent can be used as a part of the model itself is also described.

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REFERENCES

Bussolin, G., 1979. Simulazione interattiva aziendale. Costruzione di un modello e risultati della sua applicazione, *Rivista di informatica.*

Forrester, Jay W., 1961. *Industrial Dynamics*. Waltham, MA: Pegasus Communications. 464 pp.

Remondino, M., 2003. Agent Based Process Simulation and Metaphors Based Approach for Enterprise and Social Modeling, *ABS 4 Proceedings*, SCS Europ. Publish. House – ISBN 3-936-150-25-7, pp.93-97.

Simon, H. A., 1996. *The Sciences of the Artificial*, (third ed.). Cambridge, MA, MIT Press.