An Agent Based Methodology to Design Serious Game in Social Field

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Abstract. Training and simulation games are a type of serious game that allow learners to deal with realistic scenarios, to test their behavior under controlled conditions and to increase their understanding of the simulated system/process. In these games, the educational goal changes the issues related to the simulation design. In particular, achieving right balance between realism and teaching effectiveness is an essential design criterion. The difficulties in designing this type of serious games are particularly evident in the social field. In fact, this area is characterized by a complexity that is hard to design in formal terms. Starting from recent evolutions in the field of social simulation, this paper proposes the agent paradigm as a methodological tool to guide the design of serious games in the social field. The PNPV game, designed within the framework of the European project "I can … I cannot … I go!" Rev. 2 (PNPV project), which aims to introduce and foster an entrepreneurial mindset among young people, is described as a case study of a serious game developed by means of the agent based approach.

1 Introduction

The effectiveness of simulation technology in education has been extensively demonstrated. According to Blikstein and Wilensky [1], simulation is an active teaching tool which is available to students and improves learner understanding of the simulated system/process.

The simulation approach finds application in the realization of serious games; serious games have had a significant effect on classroom education as well as on training programs [2].

Serious games based on the simulation approach are called training and simulation games (TSG). TSGs adopt/are based on the principles of problem-oriented learning and have been applied in a number of fields: from flight simulators to the Virtual Lab [3]. TSGs are also used in the social field where the object of study is the social process.

Creating effective and attractive learning environments is essential for motivating learners, enabling them to embark on engaging and challenging educational paths [4]. TSGs create an interactive learning environment that allows learners to deal with realistic scenarios and test their behavior under controlled conditions.

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As pointed out by several authors [5, 6], the design of serious games is still an artisan process and no proper guidelines exist based on a validated methodological approach. Moreover, in the specific case of TSGs, the design is often driven by the simulation goal, thus shifting the emphasis from the educational aspect to the realism of the simulated system.

For this purpose, a methodology for designing and developing TSG can be applied in the social field, where the design also has to cope with the difficulties arising from the complex nature of social systems [7, 8].

The proposed method is based on recent developments in the social simulation research field and intends to adapt the agent-based design approach to design and develop a TSG in the social field.

According to Nigel [10] "human societies are complex …the result is that it becomes impossible to analyse a society as a whole by studying he individual within it, one at time…"; moreover, in this context ensuring that the simulation environment is totally realistic may no longer be a design goal per se. Instead, achieving the right balance between realism and teaching effectiveness is an essential design criterion.

This paper describes the agent-based simulation approach in social sciences, and starting from the principles of agent-based simulation design presents the methodology used to design the serious game PNPVillage. In particular, this work also aims to clarify under which conditions the agent-based approach could be an effective solution in serious game design.

In the following section the application of agent based approach to simulate social system is described. Then, a new methodology for designing and developing TSG is proposed. Finally the experience of designing PNPVillage is reported. PNPVillage is a serious game developed within the framework of the EU-funded project "I can … I cannot … I go!" Rev. 2 (PNPV project) that aims to create a training model and tools for the acquisition of knowledge and entrepreneurial skills.

2 Agent Based Simulation in Social Sciences

According to Conte et al. [6], simulation is a research tool that reproduces a real system or process by means of an artificial system and provides useful and often essential insights into a large number of scientific and application sectors.

The core of simulation is the model. The models used in computer simulation are based on formal representation of the system under analysis that can be implemented in a simulation program.

In the last five years, interest in multi-agent based simulation (MABS) has grown continuously [11–13]. Multi-agent systems are software systems consisting of independent entities, called agents, each of which is able to interact with the surrounding environment according to a predetermined behaviour.

The features of the MABS model can be summarized in the following points:

- the system is built on independent entities, called agents;
- the agents can communicate with one another and with the environment;
- the agents have a proactive behavior;
- the system is intrinsically distributed.

As observed by Davidsson in [14], "MABS should not be seen as a completely new and original simulation paradigm (…) it is influenced by and partially builds upon some existing paradigms, such as, parallel and distributed discrete event simulation, object-oriented simulation, as well as dynamic micro simulation."

MABS is the right tool to analyze situations where distributed entities with an autonomous behavior are present. Moreover, the pertinence of MABS to analyze a system should be derived by determining whether that system can be suitably modeled in terms of entities and behaviors or not.

Using the MABS model, the outcome of the simulation at the macro level derives from the evolution of the interaction among the agents at the micro level, making it possible the study the emergent behavior of a system.

This characteristic highlights the close relationship between MABS and the empirical study of social science models. A large number of papers underline the importance of simulation as a tool to study social and biological systems, and numerous authors have recognized the effectiveness of MABS for the investigation of these fields [15].

In [16] Davidsson introduces a schema that facilitates understanding of the relationships among three scientific areas: Agent-Based System, Social Science and Computer Simulation (Fig. 1).

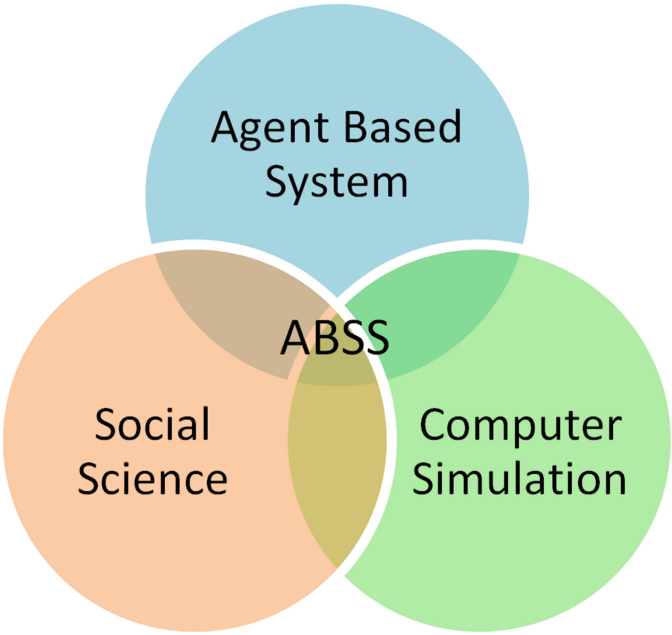

Fig. 1. The three areas constituting ABSS and their interrelationship [16]

The intersection between the Agent-Based System and Social Science concerns the study of social aspects of the agent system (norms, institutions, organizations, competitions). The intersection between Social Science and Computer Simulation focuses

on the possibility of simulating social phenomena with computers using any available simulation method and model (Social Simulation - SocSim).

Agent-based social simulation (ABSS) is a specific sector of SocSim aimed to simulate and investigate social phenomena on a computer by means of agent technology.

Agent-based modeling represents an innovation with respect to traditional simulation models. While traditional approaches in general formalize the system's behavior through a set of mathematical relations, in ABSS, the behavior of complex social systems is simulated modeling the single entities and their interactions.

In other words, the system behavior is not modeled at the macro level, but emerges from the composition of the behaviors of the single entities interacting with each other and with the environment (emergent behavior). This feature avoids introducing strong assumptions a priori, such as the rationality assumption of decision-makers necessary for game theory-based models.

Moreover, in agent-based models each agent can adapt to circumstances, thus showing a sort of learning ability.

ABSS in the social sciences typically includes a large number of autonomous entities with very simple behaviors in order to allow researchers to analyze and understand how tiny modifications in the behaviors of these agents can change emergent behavior at an aggregate level.

As an example, ABSS is now considered to be a useful tool that allows researchers in the field of economics to simulate market dynamics and thus validate economic models. In fact, the computational study of economies modeled as evolving systems of autonomous interacting agents has given rise to a research sector known as Agent-based Computational Economics (ACE). ACE is a specialized area of economics of the basic complex adaptive systems paradigm [17, 18].

3 From Simulation Design to Serious Game Design

The typical phases involved in the definition of the simulation model are shown in the following figure (Fig. 2).

The abstraction phase generates a simulation model consisting of a formal description of the system or process. The level of detail of such a formal description must be suitably defined so that only the subset of relevant aspects of the target system is reproduced.

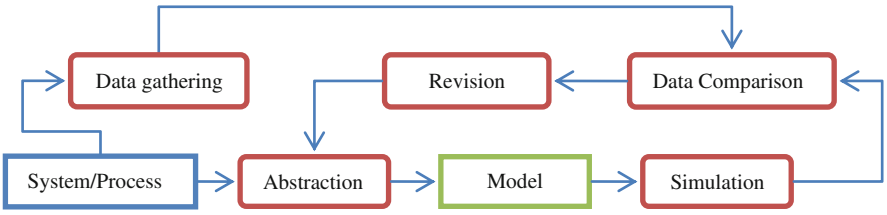

Fig. 2. Simulation model definition and validation scheme [13]

This process implies great simplification of the real world system to be analyzed and, as a consequence, it enhances the importance of correct model validation.

Models must be kept as simple as possible, provided that they are able to show valid behavior, i.e., coherent with the actual evolution of the system or process under analysis.

During the simulation phase, the behavior of the model is executed. The model generates a collection of simulated data that are to be compared with the real ones in order to adapt the model and make it closer to the target system.

The abstraction process of an ABSS involves the following steps:

- identifying the active entities (agents) of the system; agents are active since they are capable of perceptions, communications, and actions;
- specifying knowledge and behaviors of each agent; agents can correspond to both physical and logical elements, and can be permanent or transient.
- defining the subsets of system state variables to be included in the agents' private data; only the agents have the responsibility for storing and updating these data. In a MABS model, the system state is thus distributed and mainly controlled by separate agents.
- modeling the environment; the environment model also denotes the relationships among system entities and anything else needed to simulate the influence of the world surrounding the system.

Starting from the simulation design process described above, the following figure (Fig. 3) shows the design process of a TSG. First of all, the educational goals of a TSG are a key element in the abstraction process and then in the model definition. In addition, we introduce the educational step as an additional validation step.

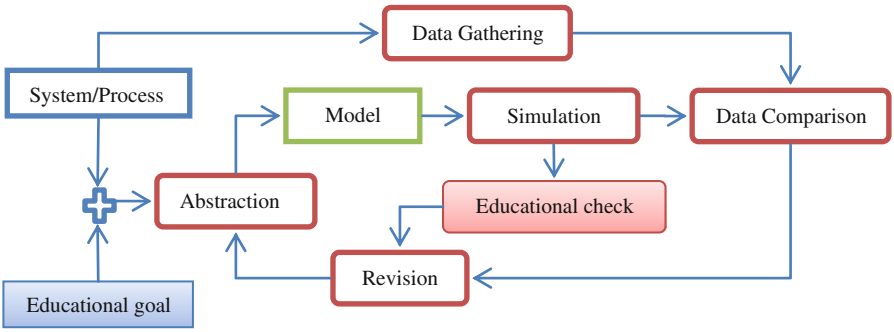

Fig. 3. Serious game model definition and validation scheme

This phase has the objective of verifying the educational effectiveness of the model from different points of view:

- allowing learners to infer the simulation model and in particular the behavior of individual agents in the system;
- validating the inferred behavioral model of each agent by means of a comparison with theoretically valid models;

- validating the emergent behavior of the system by means of a comparison with theoretically valid models at the aggregate level.

The proposed process allows the designer to check the validity of the simulation model from the point of view of realism as well as from an educational point of view, leading to the creation of an educational environment that allows learners to cope with a complex environment similar to real social systems and to acquire specific knowledge of the behavior of individual actors.

4 "I Can … I Cannot … I Go!": The PNPV Project

PNPV Village is a web-based game [19] for testing the skills of students in the management of a tourist resort (Fig. 4), and it has been developed according to the following general aims:

- to encourage competitive dynamics among students;
- to create a simulated environment resembling the real world as closely as possible, allowing students to understand the elements of complex situations;
- to promote self-monitoring, by means of indexes that summarize market trends and aid/facilitate interpretation;
- to allow students to define their strategy;
- to create a learning process by which students work initially in a simple environment and then gradually test their skills in a more complex environment.

Fig. 4. A screenshot of the game user interface

The tourism market simulation in the PNPV game has been designed according to the ACE theory. In the following sections an analysis of the main phases of game design is presented.

4.1 Educational Goal

The educational goal of the game is to develop students' knowledge and skills in the management of a tourist village.

The game focuses on the following topics:

- marketing policies: market segmentation and market dynamics;
- financial and organizational management;
- social responsibility.

The market has been segmented into 5 types of customers in order to facilitate understanding of the market and to foster training in the marketing policies needed to meet customer preferences. Each type of customer is characterized by different preferences and by a different purchasing propensity, resulting in a different way of evaluating the various offers.

The segments into which the market has been divided are:

- VIP, customers with a high disposable income looking for high quality services as well as relaxation and well-being;
- Business, customers with a high disposable income who are looking for accommodation with a wide assortment of services;
- Young people, customers aged between 18 and 25 years with a low disposable income who are looking for sport and entertainment services;
- Middle Family, customers with a low disposable income who are looking for children's entertainment services
- Working Family, customers with a low disposable income who are looking for inexpensive services.

In PNPVillage several marketing tools that allow students to implement the marketing strategy of choice and position their product on the market have been included. These enable students to define: pricing policies, communication campaigns and advertising. PNPVillage also includes a series of levers that allow students to cope with the main aspects of managing a resort, such as the management of tourism infrastructure, accommodation services and staff.

4.2 Abstraction

The definition of the model started with the analysis and identification of all the actors and their interactions. This process is the result of synergistic activity between the domain expert and the multi-agent systems specialist.

The first step was to choose the structure of the market. In this case, the educational goal and the simulation goal overlapped. In fact, in order to promote competitive dynamics, all the villages operate in a single simulated market. In this way, the result obtained by a single village does not depend just on its own choices but also on those made by all the other groups. Each village competes in an environment very similar to the real world, where the success or failure of a business is determined not only by personal ability and entrepreneurial skills but also by the behavior of its competitors.

The model consists of four main groups of agents:

- Customers.
- Advertising campaign agents.
- Villages.
- Advertising brokers.

Below, a general view of the interactions between the different types of agent is presented (Fig. 5).

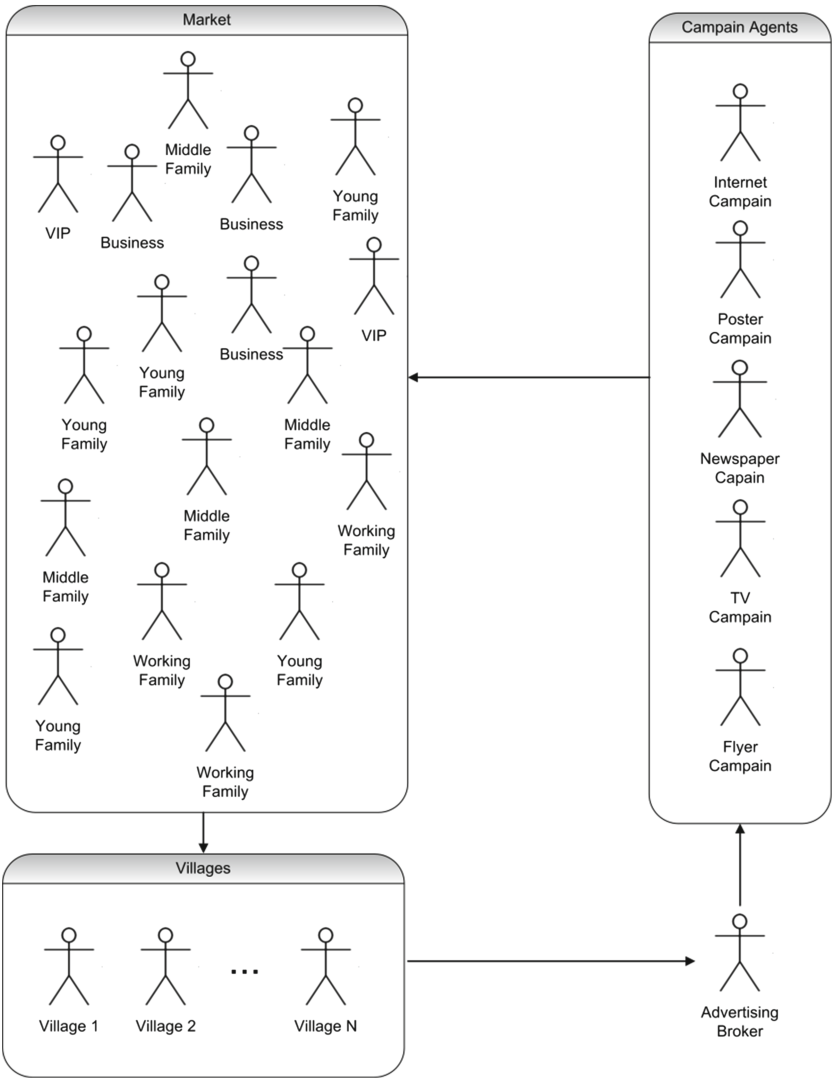

Fig. 5. The PNPVVillage agent societies

The villages are semi-autonomous agents that represent the resort. These agents are customized by the players, who can change their behavior through the decision-making levers. The main goal of the village agent is the promotion and sale of their vacation packages to the customers in the market.

The description of single agents in the model is not the main objective of this work. For a complete description of the simulation model we refer to Allegra et al. [19].

4.3 Data Comparison

The experience of the domain expert is the main element used to revise the model, including how well it corresponds to reality. Starting from the trend in the tourism market in the last few years and taking into account all the strategic and operational levers available to the players, the domain expert has provided the data used to perform the data comparison.

These data were used to verify the correctness of the model and possibly vary the characteristic behavior of the agents in the revision phase.

4.4 Educational Check and Revision

The educational check phase took place at two different times. Firstly, a group of researchers were involved in testing game activities. The goal of this step was to debug and tune the main simulation parameters.

Moreover, starting from the gaming experience the researchers were asked to infer the behavior of individual actors. The objective of this activity was to balance realism with the educational purposes of the simulation. In particular, the behavior of the single agents was made as explicit as possible to the players.

An analysis of the customer agent's behavior is given as an example. In the model, we defined a different customer agent for each market segment. The customer agent's main goal is to contract and buy holiday packages. Each agent is characterized by specific preferences that affect the contracting mechanism and evaluation of offers.

During the educational check we chose a single cycle of contracting for the customer agent. If no offer satisfied the agent's requests, he would leave the contraction phase without buying any holiday packages. The choice of a single cycle of contracting can lead to high rates of market dissatisfaction, but at the same time, it allows students to highlight the preferences of each type of customer agent; this can lead students to make informed choices guided by a more precise understanding of customer behavior.

The second phase of the education check consisted in repeating the process described above in a trial that took place in two classes of a technical institute for tourism.

The educational check was carried out during the testing phase using two types of controls: an active check and a passive check. The active check was performed by administering tests to check whether the educational content had been assimilated by the students. The passive check was performed by checking if the strategic and operational decisions taken by players of the game were consistent.

The game provides two types of decision-making levers: the strategic levers and operating levers. The strategic levers have a declarative character and represent the stated goal of the group on the basis of which the teacher has to assess the consistency of the group's operational decisions. For example, at the beginning of the game, the students have to define the customer type they intend to focus on. They can change their target customer at any level if they think that this will produce better results. Instead, the operational levers determine the results of the village.

Using the strategic levers, players set goals to be pursued through appropriate operating levers. Two main indexes have been defined, the Visibility index (VisIndex) and the Value for Money index (VfM), in order to check the consistency of the user choices; the operational levers have different influences on the VisIndex and VfM indices, depending on the type of customer.

The VisIndex measures a village's market visibility, in relation to a particular market segment. The level of a village's visibility will be calculated as a function of the investments in communication made by all the villages, for each communication channel.

The VfM is a parameter expressing the quality of the operational choices made by a single village in relation to the different types of customers. From the customer's point of view, it is the main element for evaluating and comparing the offers made by the various villages.

The following figure shows the relationship between the various levers and costs, revenues, VisIndex and VfM, which are different for each kind of customer (Fig. 6).

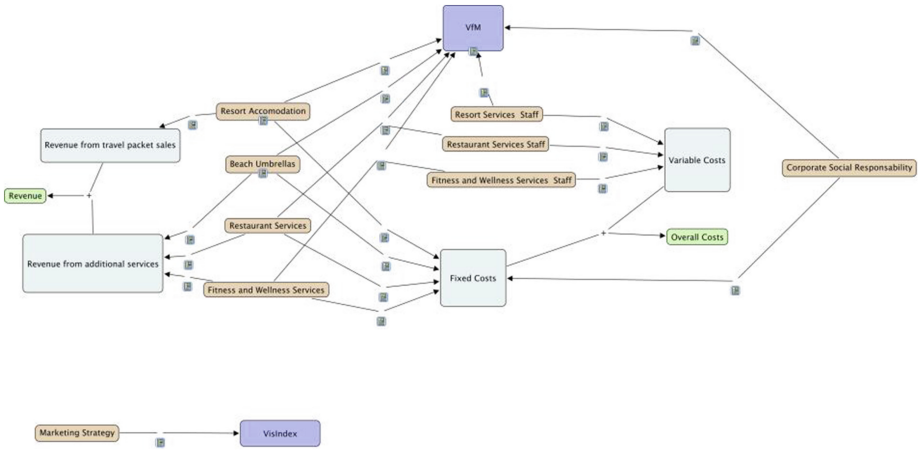

Fig. 6. The network of relationships between the levers and the game indexes

5 Conclusions

The paper proposes a new methodology for the design of training and simulation games in the social field. The proposed methodology adds new key phases to the traditional design process of a simulation, namely educational goals and educational checks.

These two phases are a key element in the design process, allowing designers to improve the educational effectiveness of the model.

As an example of an application of the proposed method, the design of the serious games PNPVillage has been described. The PNPVillage is a serious game aimed to encourage and support entrepreneurial mindset in young people and allows students to progress from a simple scenario to a more complex one with a step by step approach [19], analysing the main concepts of village management and taking decisions to improve competitiveness and results.

The adoption of the multi-agent approach in designing the PNPVillage allows the teachers:

- to control the game evolution by means of an in-process tuning of the agents behaviour;
- to simulate gradually more complex scenarios;
- to facilitate the system evolution comprehension and to improve the efficiency of the debriefing activity.

At the time the process serves the students to follow the real actions of each agent and thus to analyse the appropriateness of their decisions in the light of the developed agent models and evaluate recognize the strong points and the drawbacks of the strategies adopted.

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