Integrating Multi-agents in a 3D Serious Game Aimed at Cognitive Stimulation

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Abstract. Therapies for cognitive stimulation must be developed when some of the cognitive functions are not working properly. In many applications there is a strong dependence on therapist's intervention to control the patient's navigation in the environment and to change the difficulty level of a task. In general, these interventions, cause distractions, reducing the level of user immersion in the activities. As an alternative, the inclusion of intelligent agents can help to alleviate this problem by reducing the need of therapist involvement. This paper presents a serious game that combines the technologies of Virtual Reality and Multi-Agent Systems designed to improve the cognitive functions in patients with neuropsychiatric disorders. The integration of different technologies and the modelling methodology are described and open new software development perspectives for 3D environments construction.

Keywords: Virtual reality, Multi-Agents Systems, Serious Games, Cognitive Stimulation.

1 Introduction

The cognitive functions are crucial for human life development. Therapies for cognitive stimulation must be developed when some of the cognitive functions are not working properly. These therapies can allow the recovery of basic functions such as attention and memory. Several strategies and technologies are being explored in this area and Virtual Reality (VR) applications is one that can be specially nominated. Virtual Reality includes advanced interface technologies, immersing the user in environments that can be actively interacted with and explored [10].

A wide range of everyday situations can be specifically developed through software designed for stimulation of the cognitive functions. Reasoning exercises can

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be repeated extensively and have their level of difficulty changed according to the patients' results.

Currently, these applications can be considered as "Serious Games" which are computer games with the goal of education and/or construction of concepts [9]. These games allow the simulation of real-world situations, providing training activities that stimulate cognitive functions and psychomotor skills.

Recently, several experiments in this area have had positive results, which are stimulating new research [8]. However, in many applications there is a strong dependence on therapist's intervention to control the patient's navigation, to change the level of difficulty of a task, to go back to an earlier stage, or to control the order of activities in the synthetic environment. These interventions, however needed, cause distractions, reducing the level of user immersion in the activities. As an alternative, the inclusion of intelligent agents can help to alleviate this problem by reducing the need of therapist involvement.

This paper aims at presenting a serious game that combines the technologies of Virtual Reality and Multi-Agent Systems designed to improve the cognitive functions in patients with neuropsychiatric disorders. The agents control user's actions register in the system and propose tasks according to his level of performance.

The game integrates a group of agents which will be responsible for managing and monitoring the performance of individuals in the tasks. The game's levels of difficulty will be controlled by agents. Agents respond to user action and build a personal trajectory of activities. The game is composed by two different rooms: one aimed to stimulate attention and concentration and the other related to memory. These rooms contain furniture and decorations similar to those used in family homes. The first game shows a room with three shelves, one beside the other, with different objects on the shelves. Some objects similar to those in the bookshelf will be randomly shown on a frame and the patient must walk to one of the shelves and click on the corresponding object. The second one presents an object associated with a number and the user must click on as many objects as were requested.

People with different disabilities can use this game, especially those who must receive stimuli of spatial attention, such as people with unilateral spatial neglect.

The game development process explored specific methodologies for agent modelling and implementation.

This work is organized into 5 sections. Section 2 gives an overview of the main themes related to this work, and Section 3 describes the adopted methodology for the game development. Section 4 presents the game prototype. Section 5 concludes the work and presents future research directions.

2 General Concepts

After an injury the brain is able to rearrange its connections and consequently, the functional recovery [7]. Based on the brain plasticity ability, the cognitive rehabilitation emerges as a strong ally for cognitive function recovering of individuals who suffered some brain damage. In general, the exercises produce a specific reorganization in various levels of neural connections, increasing the recovery process of cognitive and motor functions.

The cognitive rehabilitation functions such as visual perception, attention and memory, the motor skills explore the 3D virtual environments potential supported by different theoretical and practical approaches [8]. In general, these applications are developed in game format to motivate the patient to do the tasks. Another possibility that has been considered in this area is the use of commercial games that are used for specific purposes. In this case, the games are known as “Serious Games”. The "Serious Games" offers activities that help users in absorbing concepts and psychomotor skills. Generally this term is used to highlight games that aim to provide, besides entertainment, experiences related to education and training [3], [9].

The Virtual Reality technology has been widely used in these games, providing opportunities to offer some situations closer to the real world. Burdea and Coiffet [10] defines the applications of Virtual Reality as a three-dimensional virtual environments that presents real-time graphics rendered by a computer, in which the user, via body position sensors or user-input devices, controls the viewpoint or the orientation of displayed objects.

In the area of cognitive rehabilitation through 3D environments, several research groups have developed and tested products for different level of disabilities. Gamito et al. [11] created a virtual environment consisting of a small town with digital robots, several buildings and a mini market where the user can move freely. The tasks stimulate the executive functions associated with activities of daily living such as personal care and identification of routes, among others. Meijer et al. [4] present a virtual environment composed of a supermarket with several groceries sections with the objective to verify the user's spatial learning by assessing the degree of accuracy that he learns the route and layout of the environment. Attree et al. [5] describe an environment where the user should observe the objects arranged around the room and try to find a specific toy car among them, stimulating memory and attention.

Despite the many research efforts addressing the development of these environments, it does not have control over the users' navigation, nor propose the tasks in an automated way. In many applications there is a strong dependence on the therapist's intervention to control the patient’s navigation, to change the level of difficulty of a task, to go back to an earlier stage, or to control the order of activities in the synthetic environment. These therapists’ interventions can reduce the level of user immersion in the simulation. As an alternative, the inclusion of intelligent agents could help to alleviate this problem, by reducing the need of therapists’ involvement.

2.1 Agents

Multi-agents systems applications have been increasing in different areas. An agent can be considered an autonomous system seeking different ways to reach pre-established goals in a real or virtual environment [12]. Another definition describes an agent as a system capable of perceiving the information from their environment through sensors and acting through actuators [13]. Every agent must have autonomy, which means that an agent has the ability to manage its internal state and its actions to achieve their goals without human intervention. An agent may have other characteristics, which have a degree of importance depending on the area in question, reactivity, adaptability, communication, mobility, etc.

Agents are classified regarding intelligence [12] into Reactive Agents, Deliberative and Cognitive Agents or Hybrid Agents.

Reactive Agents are simple agents based on simple event-response model, reacting to environmental changes. These agents have no memory and thus are unable to plan future actions [14]. The idea of this architecture is that a global intelligent behavior is achieved by the interaction of several simple behaviors.

Deliberative and Cognitive Agents are based on models of human organization such as communities and hierarchies. These agents can interact with other agents using complex languages and messaging protocols. They have explicit representation of the environment, community members and can reason about actions taken in the past and plan future actions. In general, have high computational complexity. Among the architectures developed for the creation of these agents, there is the architecture Belief, Desire and Intention (BDI) which is based on mental states: beliefs, desires and intentions [13].

Hybrid Agents have reactive and cognitive architectures components. They are not purely reactive or cognitive [13].

A multi-agent system is composed of two or more agents who have a set of skills and plans in order to achieve their goals [15].

2.2 Agents in 3D Environments

In the area of Virtual Reality (VR) the use of MAS is still new however we can find some applications in areas of education and training. Some of these applications are described below.

STEVE (Soar Training Expert for Virtual Environment) is an animated pedagogical agent embedded in a 3D simulation system designed to assist students in naval training [16]. STEVE is considered an intelligent tutoring system that integrates methods from three research areas: computer graphics, intelligent tutoring systems and agent architecture [17].

Active Worlds is a business and personal applications platform for online distribution of interactive 3D content in real time. Personal applications can build personal learning environments, as the River City project, a virtual environment for science classes in high school. In this virtual world, students travel in time bringing their skills and technologies of the XXI century to solve problems of the nineteenth century. The students work with research teams to help a city to understand what the causes of the residents' sickness are. The students, who are represented by avatars, interact through a chat with the locals, which are software agents that respond to questions from students [18].

3 Game Development Methodology

The game development methodology was organized into four phases: (i) study of rehabilitation process using Virtual Reality, (ii) study of the technology of virtual environments and multi-agent systems, (iii) modelling and developing the game, (iv) evaluation the game for the rehabilitation process.

In the first phase we studied the levels of cognitive development of an individual, the consequences of brain injuries, the cognitive rehabilitation process and the experiences with the use of VR as a tool to support the rehabilitation process. A physician gave the initial software requirements, discussing the tasks and the difficulty levels.

At the second phase we studied and analyzed the technologies adopted for development of virtual environments and multi-agent systems. For this, we conducted a survey of these tools prioritizing those that were free. From that, the tools were chosen and tested. A development of a prototype involving the integration of these tools was also performed. We did not find in the literature works that describe how to make this integration.

Then in the third phase the system was modelled and the first prototype was implemented. After that we had a meeting with a physician to assess the tasks, the level of difficulties and the game interface.

In the last phase some experiments will be made with a small group of patients to evaluate the game usability. Then a new evaluation will be conducted with experts.

3.1 Game Modelling

For modelling the game we conducted an interview with an expert in the application area to get the initial software requirements. Then a lexical catalogue using LAL (Language Extended Lexicon) [26] was specified to register and document the requirements [25].

The goal oriented framework i* (i-star) [24] was adopted for modelling the game and it models the contexts based on the dependency relationships among actors. Actors depend on each other for goals to be achieved, for resources to be provided, for tasks to be performed, and for softgoals (non-functional requirements) to be satisfied. This framework defines two kinds of models: the Strategic Dependency (SD) model and the Strategic Rationale (SR) model.

The Strategic Dependency SD model consists of a set of nodes and links defining dependency between two actors. One actor (called depender) depends on one or more actors (called dependees) through a dependency (either an end node or a component node called dependum). A dependum may be one of four types: a softgoal, a task, a resource or a goal [24].

The Strategic Rationale (SR) model expresses an actor's reasoning. Rationales are modelled through means-ends relationships, task decompositions, and softgoal contributions. The means-ends relationship represent relationships like a goal to be achieved, a task to be done, a resource to be produced, or a softgoal to be satisfied named as the "end" and the "means" alternative to achieve them. The tasks decomposition are associated with 'how to do something' and can be modelled in terms of its subcomponents decomposition which can be: goals, tasks, resources and/or soft goals [24].

We defined four agents that are responsible for planning patient care, controlling the interactions in games, analyzing the performance of the patient and setting up the environment. The SD diagram in Figure 1 helped to identify these agents and users and their relationships. For example the planner depends on the analyser to change the protocol and the analyzer on the other hand depends on the controller to provide the patient game interaction history.

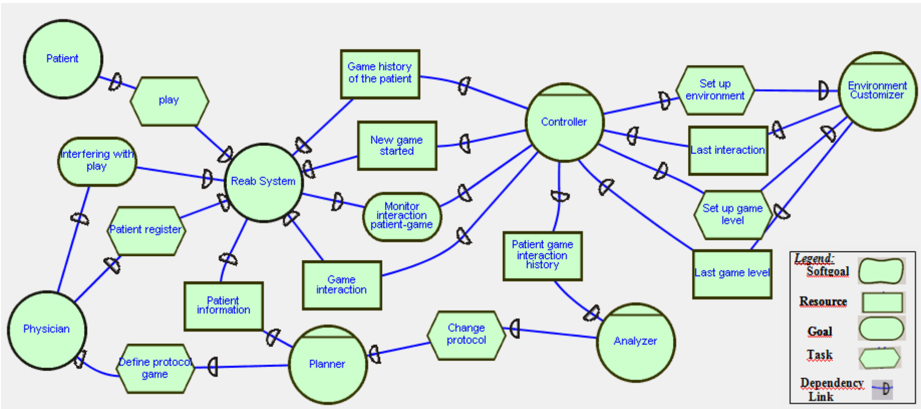

Fig. 1. Strategic Dependency (SD) model

The i* framework in the SR Diagram details the rational of each agent by describing how the goals are archived, the task performed, the softgoal satisfied and the resources obtained. The Figure 2 is the SR game for the agent Analyser which is responsible to archive the goal “performance evaluation of the patient”. This goal is satisfied by the task “assess patient performance” that is decomposed into three tasks (capturing treatment protocol, capturing game history and comparing the expected performance) and the goals “rated performance”. The task “capturing game history” depends on the Control Agent to provide the information “patient game interaction history”. The goal “rated performance” is satisfied by performing one of the tasks “continue in the same plane” or “suggest change of plan”. This last task will provide the resource “change protocol”.

4 The Game Prototype

A first prototype was implemented to validate the requirements and verify the game usability with an expert in the CR area. It was built based on i* models defined before.

The game environment integrates the technologies of Virtual Reality and Multi-agent Systems and aims to stimulate the cognitive functions such as attention, concentration and memory. The levels of difficulty of the proposed activities are controlled by agents.

For the implementation of the agents and 3D environment we studied several languages and frameworks, verifying the technological compatibility among them. Thus, various combinations were tested to achieve this goal [19]. Among the technologies studied, we adopted the following languages: X3D (eXtensible 3D) [20], JAVA [21] and the framework JADE (Java Agent Development Framework) [22]. To integrate these three applications we used the NetBeans Platform [23]. The agents' behavior is based on the Cognitive Model [12]. The agents have goals and desires that are combined to control the difficulty level of the game.

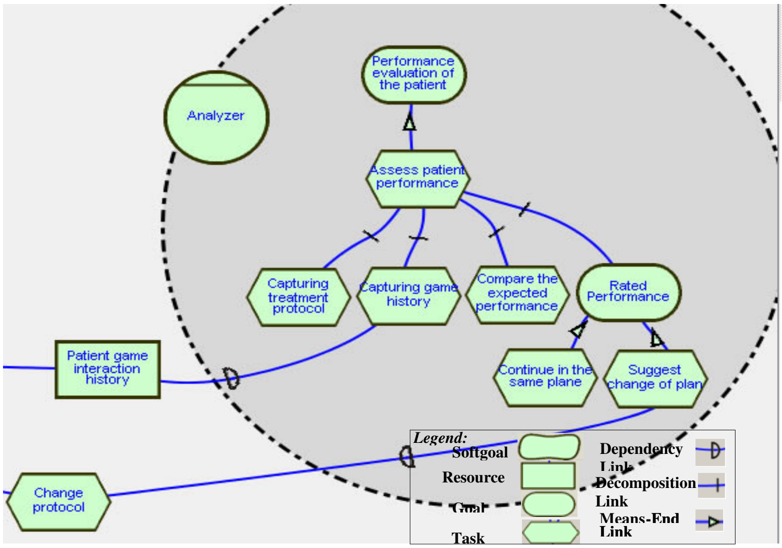

Fig. 2. SR Model of Analyser Agent

The games are distributed into two rooms. The first game has bookshelves, with different objects on them. Randomly objects are shown on a table and the patient must walk to one shelve and click on the similar one. An agent will monitor the time and the user interactions with the environment, controlling the rights and wrongs answers, changing the difficulty level of the tasks according to their performance.

Another game will occur in another room (a kitchen) and will comprise several objects that are part of day by day life of an individual. In this activity, the degree of difficulty is greater than the initial exercise described above, because the patient will deal with two variables: an object and a number 'n', which will be presented at the scene. The user must click on 'n' similar objects. The game's difficulty level will rise by increasing the number of objects to be selected and by the introduction of distracters in the scene as a sound or a blinking object. The second game scene is in the Figure 3.

Aiming at analyzing some aspects of the prototype we made an evaluation with a psychiatrist, based on a script that follows the concepts of consolidated methodologies. The psychiatrist evaluated this first prototype by analyzing those aspects: Navigation facility, Learning facility, Response time, Realism of scenes, Pleasantness of the scenes, Adequacy of the objects in the tasks, Matching Colours and Adequacy of the difficulty level of the game.

Fig. 3. The kitchen where the second level game will be developed

5 Conclusions

Democratizing access to new treatment practices for neuropsychological disorders has been the target of several research groups. In Brazil, we observe a growing interest in this area. In this sense, we need new software and new models of treatment, where patients may have more unrestricted access to the exercises and the therapist can monitor the result at distance, reducing the need for constant face-to-face contacts. Some types of exercises could be done at home, expanding the possibilities of rehabilitation. Thus, in this case, the virtual environment must have some mechanisms to control user navigation and generate automatic reports to the therapist. The Virtual Reality technology is widely used to give cognitive and motor stimulus for patients with different impairments.

However, the development of such software depends on knowledge of different fields of expertise. The modelling, the design, the implementation, the programming of intelligence and the assessment are examples of tasks present in the development process.

This paper presented the initial results of a project that has two objectives. The first one is associated with the technical questions related to the intelligent agents modelling that will be in the 3-D virtual environment. The other aims at finding the combination of technologies to support the integration of intelligent agents within the 3-D environments.

To develop this environment we adopted a methodology composed by 4 steps supported by a multidisciplinary team. We considered that we found a good solution for this problem. The integration of X3D, JAVA, JADE and NetBeans created a new combination of technologies that worked efficiently in our initial tests.

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