Virtual Environments For Training Visually Impaired For A Sensory Substitution Device

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***Abstract*—Virtual reality represents an emerging technology, which can be successfully used to develop training tools in many domains, such as military, space, education or healthcare. The current paper proposes a training strategy for a sensory substitution device in order to improve the ability of visually impaired people to be autonomous, thus to increase the quality of their lives. The core of the strategy is a highly interactive virtual training environment, composed of 3D scenes simulating both realistic and imaginary settings. The training is based on gamification principles, as the virtual environment is designed as a highly immersive serious game, with essential elements such as quests, rewards or increasing complexity of tasks which can maintain its users motivated and help them acquire useful day-to-day life skills. Also, a series of mini-games are available in the training environment, as repetitive actions can facilitate the improvement of specific skills. By using appropriate hardware equipment, the virtual training environment can be rendered to the visually impaired users through acoustic and haptic means. The paper presents our proposed training strategy based on virtual reality in the context of numerous challenges of offering efficient training experiences to users with special needs.**

Keywords*—*virtual training environment; visually impaired; virtual reality; serious games.

I. INTRODUCTION

Worldwide, there are 285 million people suffering of some form of visual impairment, with over 39 million of them being completely blind. Even if these numbers seem to have been reduced in the last 20 years, visual impairment still represents a major problem, affecting considerably the life quality of its sufferers [1].

Visually impaired people must confront many difficulties in their lives, mobility probably being the most severe one. Many devices have been developed to facilitate the safe movement of visually impaired, the white cane being the most popular and durable. Unfortunately, most traditional or smart devices fail to succeed in various areas, so a better substitute should be found [2].

Our project, Sound of Vision (SoV), has the goal of using the advantages of an emerging technology, virtual reality, to create a vision substitution device which solves the above mentioned problems. It uses appropriate hardware equipment, in the form of a headset with camera, head movement detection and speakers and a vest which sends vibrations patterns to the wearer. In order to get accustomed to our device, the users must train specific skills and practice navigability, so they can understand the use of various available audio and haptic models. This training can be performed by the use of virtual training environments, complex virtual scenes, which simulate accurately real world settings. The training process can be very useful to help the visually impaired people get accustomed to the device and acquire specific competencies, which can later be applied in real life, in order to increase the autonomy of the visually impaired and thus, ameliorate their quality of life [3].

In the following chapters, we are going to study the effectiveness of using virtual reality for training in different domains, we are going to present the vision substitution devices with their drawbacks and, finally, we are going to describe the virtual environments for our proposed model.

II. Training Using Virtual Reality

Training can be defined as an activity which has the goal of communicating instructions and information to a person in order to ameliorate their current performances and help them achieve the desired level of knowledge or competencies [4]. Traditional methods of training, relying on theory and paper-based approaches, are not efficient anymore in many domains. Unfortunately, certain training procedures involve traveling to inaccessible places, working with dangerous products or being exposed to certain factors which could endanger the life of the trainee or of those around them. This is why the idea of simulating all of these situations in a realistic manner can represent a solution to all these problems.

Virtual Reality (VR) is an emerging technology, which creates a highly realistic computer-based environment, which could have many applications in day-to-day activities. Virtual Reality has continued to evolve over the time, focusing on the authenticity of the immersion and stimulating major senses of its users: sight and hearing. For the exactitude of the artificial environments, additional devices are usually used: head mounted devices (HMD), steering wheels or pedals [5].

There are many advantages of the use of virtual reality for training environments, such as the possibility of creating a big variety of environments, great accessibility and flexibility to the users' needs, the possibility of training for dangerous situations, adding entertainment and fun to the training process, assuring continuous and instant feedback [6]. After analyzing various research papers from different domains, we selected the most relevant ones which use virtual reality for training, taking into account its previously mentioned advantages.

Probably the most famous domain which requires special attention to the training process, education has started integrating modern technologies in its approaches. There are people who have difficulties in adapting and understanding traditional methods of learning, for whom the use of virtual training environments (VTr) may prove useful. Certain events can be simulated and trained in a realistic manner, stimulating and motivating the trainees. VTrs can also be capable of improving the analytical and exploratory capacity of their learners, by exposing them to new situations in an original way. Another possible approach of using virtual reality for training in education is the creation of synthetic characters, which can take the role of a teacher. These are just a few examples, the opportunities are countless, as a great variety of environments could be created with the help of virtual reality, for simulating past, present or future situations [7] [8].

Virtual reality becomes more and more popular in medicine: from surgical simulations, to psychological disorders treatment or medical education, this new technology can contribute to the discovery of new methods of evolving the medical field. Students and clinicians can have access to huge amounts of information, as virtual reality can help them explore the interior of the human body, the inside of the organs or blood vessels. Basic or complicated medical procedures can also be trained using virtual reality and repeated as often as needed [9] [10].

III. Visual Sensory Substitution Devices

The traditional white cane has been the main mobility tool for visually impaired people for many decades. It has a double role: firstly, to guide the blind person in the environment, and secondly, to alert the others about the person's condition. It also has some disadvantages, such as the incapacity of detecting head-level or moving obstacles, the short distance of object detection, which also decreases the speed of walking, people's confidence and speed of reaction. Over the years, improved versions of the traditional white cane have been developed, by integrating the use of technology and creating so called "smart canes", usually based on ultrasonic sensors [2].

Researchers are permanently looking for an efficient model for vision substitution, as a complementary device or completely replacing the idea of a white cane. Various researches studied the use of sounds or haptic patterns for creating image representations [2] [11]. The matter is delicate, as the limitations of the hearing must be taken into account and an efficient pattern for mapping the images on sounds must be established [12]. Many electronical devices designed for visually impaired, even if successful in preliminary tests, haven't been too popular among their users [13]. Since the development of virtual and augmented reality, new methods of designing models for helping visually impaired people have emerged, which can represent the solution to many problems. One of the approaches involves the development of virtual environments which are represented through acoustic means. Previous researches mention the creation of simple virtual environments, which can be used with Visual-to-audio Sensory-Substitution-Devices, showing promising results [14]. Usually, in the virtual training environments, some type of tracking system is used to detect the movement of the user's head and assure the natural interaction with the virtual world. The process of extracting the exact distance between the user and the virtual object is essential, as this information constitutes the foundation of the sounds' representation [15] [16].

Our project, Sound of Vision, uses appropriate hardware equipment in order to represent the environment through acoustic and haptic means, thus creating a vision substitution device [17]. We considerate that our proposed approach is the only one capable of encouraging the constant, long lasting process of training, in order to help the visually impaired achieve the required performance. In the following chapter, we will describe the virtual training environments created to help the training process for the vision substitution device.

IV. Sound of Vision – Virtual Training Environments

The Virtual Training Environments represent complex 3D scenes, simulating both realistic and imaginary settings. The main goal of the VTr is to help the user train and acquire specific skills, mandatory for increasing their familiarity with the Sound of Vision system. The final version of the virtual training environments must include three distinct modules: a realistic realm, a fantasy realm and a series of mini-games. The realistic realm presents real life settings, where the user must perform basic day-to-day activities. The fantasy realm represents an imaginary world, which integrates gamification elements and an attractive gameplay, while still focusing on the training process. Finally, the third module represents a series of mini-games, which have the goal of training specific skills in controlled environments, with increased levels of difficulty.

A. Realistic Realm

The realistic realm represents an ensemble of realistic 3D scenes, where the user must perform a series of tasks, simulating day-to-day activities, such as visiting a friend, going to a restaurant or taking the bus. The realistic scenes include the interior of a house (Fig. 1), a small city (Fig. 2), an office building's interior, two universities and a mall, in order to include a high variety of real-life simulating environments, where the user must perform usual activities. All the scenes contain real-size scaled objects, animations and localized sounds, in order to improve the realism, making the users believe they are performing a series of tasks in real life settings. In order to advance, the user must complete several quests, in a precise order, passing from one 3D scene to another. The quests simulate basic activities and they have increased levels of complexity and difficulty.

The realism of the city scene is accentuated by the presence of a module which allows the users to customize the weather conditions (sunny/rainy) or the time of the day (day/night cycle). The weather condition customization module uses a Rain prefab which has a corresponding script attached to it. When certain special keys are pressed, particle systems are generated in order to simulate rain drops falling. Based on the user's input, there are multiple weather conditions: sunny, light rain, medium rain or heavy rain. At this final stage, the rain sounds, wind and mist intensify, in order to maintain the realism and make the user believe they are walking in torrential rain. The day/night cycle is determined using a Sun prefab – it is actually a light source, which ca be rotated 360 degrees around the horizontal axis in order to change the hour of the day based on the user's input.

This small city is a so called hub level, connected with almost all the other scenes of the VTr. From the city, the user can travel to the mall or to the universities, by using a customizable travel system.

Fig. 1. House interior (Office)

Fig. 2. Small city

In order to assure the traveling between two distant scenes or two points of the same scene, we created this travel module, which can be customized with 3D sounds and moving objects, based on the purpose of use. The travel system can thus simulate an elevator or a bus ride, with appropriate environmental sounds and various random moving objects, with various sounds, spawning around the user. This object spawner contains a list of sounds, including a horn, an ambulance or a door barking, in order to represent the 3D objects passing near the user and making them believe they are actually in a moving bus. In the other scenes, the tasks are diverse, stimulating the training process in different situations. For instance, in the office interior, the user interacts for the first time with the stairs, task repeated later in the universities or the mall scenes. The actual scenes of the two universities are based on real settings of the University Politehnica of Bucharest and the University of Iceland, including buildings with classrooms, stairs, décor elements and their surroundings. Finally, the mall scene includes a considerable number of shops, restaurants, coffee shops or a cinema and the user must perform regular tasks, such as dining in a restaurant, listening to a concert or shopping at the supermarket. The tasks can be observed on a head-up display (HUD), in a precise order, which must be respected by the user. This HUD is important for the training process, when the user is guided by an assistant. In order to complete a certain quest, the user must reach one or more hotspots, situated in various positions in our scenes.

The VTr is implemented using Unity3D, by taking advantage of the Entity-Component design pattern and the C# programming language. We use a series of singleton classes, as managers for performing certain tasks in our application: audio management, level management or user management, for instance. There is also a quest manager, necessary in every scene, as it loads a specific XML file containing the exact order of the quests, as well as their detailed descriptions. The quest manager has the goal of determining when a new quest has started, when it has been successfully completed or when all the goals have been completed and a new scene must be loaded. This manager also uses an instance of an HUD manager, which has the goal of displaying the quest list on the screen, as previously described. The realism of the scenes is also accentuated by using animations and sounds. The audio part consists of playing specific sounds when the user reaches a hotspot or playing a general ambient sound, in harmony with a certain scene (for instance, the noise of a bustling city or a classroom full of students). There are also certain 3D sounds, attached to objects, in order to guide the user towards a certain destination or simply to make the environment more authentic.

Voice recordings exist in both realistic and fantasy settings, in order to describe specific tasks to the user.

B. Fantasy Realm

The fantasy realm has the goal of creating an entertaining and original environment, based on gamification elements. The user still has quests which must be completed in order to train specific skills, but this serious game must also contain attractive and ludic elements. The fantasy realm will concentrate on the creation of a strong emotional immersion, letting the users take their own decisions.

The action takes place on Planet Eternity, the main character being Hope, a young wizard. Eternity was an idyllic land, immune to diseases, unaffected by wars. After a big tragedy, the player must rebuild the planet, by restoring the so called sites of power and defeat the Umbras, in order to save the fate of the habitants. The decisions taken by the main character influence the storyline, as they can change the fate and the future of their loved ones. Based on a linear storyline, the fantastic scenario focuses on the idea of exploration and integrating nicely various mini-games. Aspects such as magical elements, sites of power, emotional connection with the other characters, as well as the desire to defeat the antagonists and save the world, can also contribute to the immersion and the motivation of playing and therefore, of training. Even though the environment is rendered only through acoustic and haptic means, a good storyline and a suitable gameplay can make the user have fun, relax, get attached to the game and also train essential competencies.

V. Testing and Validation

All the previously mentioned virtual training environments have been developed and tested internally by the development team. Preliminary test results were encouraging and after some minor changes, all virtual environments will be completely integrated with the Sound of Vision device.

A series of simple virtual environments also exists: basic scenes, with a reduced number of simple objects (boxes, spheres, walls). These virtual environments have been used for two months in order to train two visually impaired people for the proposed SoV system. The evolution of the users' performance was impressive and the understanding of the haptic and audio models increased considerably during the training process. We consider that the virtual environments were an essential part in this process, before being able to proceed to real-world training with the system.

VI. Conclusions

Virtual reality is an emergent technology, an innovative and useful tool for training in various domains. In the entire world, there are 285 million people suffering of visual impairments [1] and the researchers are still searching for suitable solutions to improve their quality of life. Our current paper presented an original approach of developing virtual training environments, as part of the Sound of Vision project. The ultimate goal is to create a suitable environment, where the users must perform specific tasks in order to achieve essential competencies, while still assuring a relaxed, experience. As future improvements, we plan to finish the fantasy realm environment, based on the previously mentioned storyline and integrate essential gamification principles. We strongly believe that these virtual environments, used with the Sound of Vision device, which provides appropriate audio and haptic means, can help the users achieve great results in the training process, by staying motivated and focused in these highly immersive scenes.

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References

[1] World Health Association, "Visual impairment and blindness", Fact sheet no 282, 2014.

[2] K. Sung Yeon, C. Kwangsu, C., "Usability and Design Guidelines of Smart Canes for Users with Visual Impairments", International Journal of Design, vol. 7, no. 1, 2013.

[3] F. Moldoveanu, A. Moldoveanu, O. Balan, "Training system for improving sound localization", 10th International Conference on eLearning and Software for Education, pp. 79, 2014.

[4] Definition of word « training », www.businessdictionary.com

[5] A. Moldoveanu, "Introduction to Virtual Reality. Lectures at Faculty of Automatic Control and Computer Science", University POLITEHNICA of Bucharest, 2016.

[6] J. Rickel, "Intelligent virtual agents for education and training: opportunities and challenges", Proceedings of the Third International Workshop on intelligent Virtual Agents, pp. 15-22, 2001.

[7] Virtual Reality Society (VRS), "Advantages of virtual reality training"

[8] J. Gratch, S. Marsella, "Tears and Fears: Modeling Emotions and Emotional Behaviors in Synthetic Agents", Fifth International Conference on Autonomous Agents, Montréal, Canada, 2001.

[9] C. Pensieri, M. Pennacchini, "Overview: Virtual Reality in medicine", Journal of Virtual Worlds Research, 2014.

[10] K.-P. Beier et al., "An Immersive Virtual Reality Platform for Medical Education: Introduction to the Medical Readiness Trainer", Proceedings of the 33rd Hawaii International Conference on System Sciences, 2000.

[11] P. Bach-y-Rita, C.C. Collins, F.A. Saunders, B. White, L. Scadden, "Vision substitution by tactile image projection", Nature, vol. 221, 1969.

[12] O. Bălan, A. Moldoveanu, F. Moldoveanu, M.-I. Dascălu, "Navigational 3D audio-based game-training towards rich auditory spatial representation of the environment", 18th International Conference on System Theory, Control and Computing (ICSTCC), pp. 682-687, 2014.

[13] F. Dramas et al., "Designing an Assistive Device for the Blind Based on Object Localization and Augmented Auditory Reality", Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility, pp. 263-264, 2008.

[14] S. Maidenbaum, G. Buchs, S. Abboud, O. Lavi-Rotbain, A. Amedi, "Perception of graphical virtual environments by blind users via sensory substitution." PloS one 11, no. 2, 2016.

[15] M. A. Torres-Gil, O. Casanova-Gonzalez, J. L. Gonzalez-Mora, "Applications of Virtual Reality for Visually Impaired People", WSEAS Transactions On Computers, issue 2, vol. 9, pp. 184, 2010.

[16] B. Gehring, "Why 3D Sound Through Headphones?", Computer Game Developers' Conference, 1997.

[17] O. Bălan, A. Moldoveanu, F. Moldoveanu, A. Butean, "Auditory and Haptic Spatial Cognitive Representation in the Case of the Visually Impaired People", The 22nd International Congress on Sound and Vibration, Florence, Italy, pp. 12-16, 2015.