A MULTIMEDIA INTERACTIVE 3D VIRTUAL ENVIRONMENT FOR EMERGENCY SIMULATION, TEACHING AND PRACTICE OF SAFETY PROCEDURES.

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Abstract

The paper presents a virtual environment that can be a powerful support in a course focused on safety procedures to be adopted in public environments (e.g. industrial sites but also supermarkets, schools and universities). It is formed by three modules for the teaching of the procedures, their practice and the assessment of user's comprehension. The created virtual environment can make the user experience realistic simulations and provide a complete set of information on the building structure and the exploitation of the main tools which are useful in case of emergency by means of multimedia contents. The considered virtual environment is fully customizable: maps are created by the users, new events, objects and procedures can be defined in order to make the tool usable in a wide set of frameworks. Currently some very common harmful si-tuations are implemented together with standard safety procedures. The pursued tests show the efficiency of the proposed tool in improving the users' knowledge of the explained safety procedures.

Keywords: safety; virtual reality; simulation; multimedia

Presenting Author's Biography

Marco Vannucci got the master degree in computer science in 2001 from Pisa University and the Ph.D. in engineering from Scuola Superiore S.Anna in 2006. His research activity includes simulation, mathematical modeling, artificial intelligence and robotics. He collaborated in several research project focusing his interest in the exploitation of simulation techniques in the industrial framework.

1 Introduction

Although the technical progress and the increasing social demand for improved working conditions contribute to limit number and gravity of the work accidents, their occurrence is still one of the most serious problems for industries worldwide. This fact led to the definition and the adoption of standard safety procedures which, if correctly put into practice, could definitely reduce the number and the seriousness of such accidents. Clearly there are countermeasures and safety precautions which are specific for each particular workplace, site and plant, depending also on the operations which are commonly performed and the materials which are handled, but many generic safety procedures are common to all the working environments, especially as far as the actions to be performed in the case of common disastrous events, such as earthquakes and fires, which can occur anywhere.

The securing of buildings and plants involves important structural elements, such as, for instance, the installation of fire doors, security exits, alarms and fire extinguishers; however, the human factor appears to be determinant in most of the emergencies, thus the training not only of the stable workers but also of the external personnel that has an occasional access to the workplace (e.g. for maintenance or cleaning operations as well as for transporting materials) plays a fundamental role for the correct adoption of the safety procedure and the correct exploitation of safety tools in case of dangerous events. Formation therefore seems the most efficient tool to prevent accidents. However, it is not easy to track the formation of everyone attending a particular workplace: while stable workers usually have to follow periodical courses on this subject, this is not always possible for visitors and other occasional workers. On the other hand, the organization of courses on safety represents a considerable investment of resources from both the companies and their employees as they require a lot of time for the mere teaching phase, the subsequent practice and the eventual final examination stage, which normally take place on the workplace with the intervention of an expert or a teacher. This huge and surely unavoidable efforts need to be counterbalanced by an actual improvement in the awareness and knowledge of the workers regards the safety operations and measures, but the results are often not completely satisfactory due to the passive nature of some courses and to the scarce repetitions of theoretical and practical lessons, which can be hard and costly to be organized. These drawbacks in the last years have been partially mitigated by the use of computers and informatics which have been massively employed for the development of tools for education on safety procedures.

In this paper a novel tool is presented, which can constitute either a useful support in a standard course for workers regarding the application of safety procedures or a powerful tool for the remote training of people who have occasional access to the workplace, in order to force them to learn the fundamentals of the safety procedures and tools which are available on the site they are going to visit. This tool, that is named VESPRO (Virtual Environment for Safety PROcedures), simulates a 3D virtual environments which can be defined by the teacher/administrator and where the most common safety procedures are illustrated in details through an intuitive interaction with the virtual objects. Moreover, the users can not only practice, but also evaluate their degree of learning through specific tests that measure both the rapidity and the correctness of the execution of the safety procedure: thus VESPRO provides the user with an important instrument to self-evaluate their skill level and the teachers with a powerful and easy tool to design tests for the learners, by customizing the level of severity of the harmful events that are carefully reproduced. The developed tool, by means of the use of a 3D virtual environment and multimedia content, is able to provide the user with a realistic experience, where it is possible to interact both with the building and the objects to be used to face the emergency. This approach results more intuitive and efficient with respect to traditional methods based on the use of books, posters, videos and courses for the teaching and the long-term comprehension of the safety procedures. The proposed software tries to overcome the previously mentioned weak-points of standard methods and can therefore be proposed as a complement or, in some cases, in replacement of traditional approaches.

The paper is organised as follows: Sec.2 describes the most common tools and techniques for the education regarding safety procedures, Sec.3 , 4 and 5 depict in details several aspects of the VESPRO software and the developed simulation environments, finally Sec.6 proposes some concluding remarks on the presented tool as well as some indications and perspectives for future work.

2 Background on existing educational tools related to safety

In the last years, due to the increasing necessity of providing the workers with a suitable formation on safety measures and procedures on their workplace, many tools have been developed to this purpose both by some employing companies, which created customised tools to be used on their own site, both by companies specialized in the production of such educational tools. Before the use of computers for these formation tasks the main tools were front lessons given by expert personnel with the aid of handbooks, posters and videos.

Handbooks and posters presents the main advantage to be very specific with respect to the environment and procedures, as they are often designed for a specific building and for the particular procedures which are adopted in that workplace: they describe the structure of the buildings (including exit paths, location of main objects of interest) and they illustrate in details the safety procedures to be adopted. Moreover especially poster are very easy and quick to examine and interpret, even during an emergency, and can provide a complete information. On the other hand they are not appealing for the users when they are in the process of learning, since they can offer only textual in-

formation which make them result too much abstract if compared to other techniques. Moreover the only tools for the self assessment of the learning level handbooks can provide are often some quizzes whose solution is separately provided.

Video courses can also provide a complete information in an immediate way and they also directly show how to perform certain operations and how the environment could appear in the case of any sort of emergency situation, with the aid of short films or animations. On the other hand, video courses are costly and, for this reason, often not customised to the particular location or workplace where the learner operates, thus they rarely provide information on the specific structure of the building where the learner should put into actions the safety procedures and on location of the relevant tools for safety. This is a fundamental kind of information, especially if the learner is an occasional visitor or a newly employed worker.

The potential of computers has been widely exploited in the last years for the development of e-learning tools. The advantage of the use of computers mainly resides on the completeness and nature of the information provided [4] [5] and on the interaction with the users allowed by such technologies. Computer based tools merge textual information, audio tracks, images and videos to provide the user with a complete knowledge basis which results more usable, clear and appealing with respect to traditional learning tools. Furthermore many of these softwares can be used on–line and allow the customization and the updating and provide suitable tools to evaluate the user's level of comprehension.

The most recent generation of educational tools for safety consists of graphics applications which allow to reproduce highly interactive virtual worlds. The level of realism they can reach in the simulation of real environments and situations is actually impressive. A detailed simulation of operating conditions, environments and tools in this framework allow the user to obtain an information which could not be successfully transferred by the other media. In the virtual world the user can freely explore the scenario he is immersed into [6] [7] and can interact with it with very few limitations which do not compromise the quality of the acquired information. By wandering in the virtual scenario the user gets information on the structure of the buildings and the position of main objects (especially the relevant ones, e.g. fire extinguishers, emergency lamps and valves) and can *directly* experience the harmful events, such as fires or earthquakes, and their main effects.

Living in the virtual world such situations can provide the user with the opportunity of learning practical notions on the use of the main safety tools and get an idea of the time required to reach a safe area of a building, notions which could not be effectively answered in any other way [8] [9], apart from practical exercises, which are doubtless more effective but not as easy to organise, especially for a large number of persons. A final but not negligible advantage offered by virtual reality simulators with respect to more static educational tool is the appeal they exert on the users with the result of keeping alive their interest on the contents of the lessons, which allows a successful teaching of the related concepts.

Various tools based on the use of virtual reality have been developed through the years for the simulation of emergency situations. Some of them focus on the transmission of the safety directives such as *WI-PIE Emergency simulator* which combines the purely educational part, where legal issues and information on the security procedures are described, with the practice phase where the user is asked to put into practice the taught concepts. Other tools pay more attention to the detailed simulation of the harmful events such as *Simulation of emergency evacuation in virtual reality* which trains the workers on the evacuation procedures to be applied in case of fires, focusing on fire and smoke propagation and on the interaction of the user with the environment for a faithful simulation on the effect of such event. *Vayersoft emergency fire evacuation simulation* is an educational software tool with similar purpose which couples an exhaustive tutorial on the safety procedures to some interactive sessions on particular tasks that can be easily customised to the needs of any company. Customization is an important aspect to be taken into consideration: in facts the possibility of creating personalized scenarios and situations is a key issue as it allows the users to get information and live certain experiences in the same environments they work everyday. Finally the recent development of computer networks allowed the simultaneous use of the virtual reality tools by different users which cooperate inside the scenario and face together the dangerous situations. Cooperation is implemented for instance in *Program-Ace Emergency evacuation simulator* which, if used on-line, allows cooperation and communication among the users and allow them to actuate collective strategies which are evaluated by an automatic system.

3 The VESPRO tool

The Virtual Environment simulator for Safety PROcedures (VESPRO) is an educational tool concerning safety procedures which exploits a three-dimensional simulator that allows practice in a virtual environment. The software is a comprehensive tool aiming both to the teaching of the safety procedures and to the evaluation of users comprehension within the expressly designed 3D virtual environment which makes the VESPRO experience impressive, realistic and fruitful. A preliminary version of such software has been described in [1], but the most recent version that is described here is far richer and more complete in functionalities, details of the simulated environment, possibilities of interaction with objects and information contents.

VESPRO has been realized by using the Python programming language [2] [3] exploiting the Panda 3D engine designed for the development of 3D applications. Panda 3D engine includes a set of libraries for the creations, management and rendering of virtual environment which can be directly bounded to the Python code and are nowadays often used for the development of

professional 3D games. Python programming language is derived from the Java programming language and preserves its advantages such as portability and modularity which are exploited in VESPRO to create personalized virtual scenarios and events.

In the development stages of VESPRO particular importance has been given to the aspects which should grant the usability of the software through time and its efficiency in terms of transmission of the relevant information. In particular, the fundamental features of this tools are:

- faithful simulation of multiple dangerous events, in order to grant an as much realistic experience as possible
- customizability, in order to allow a company to easily create its own virtual scenarios where users will be provided of any form of information useful in the case of emergency
- practice and evaluation phases to couple the purely educational phase with the assessment of the quality of the user's understanding of the explained procedures

As far as it concerns the customization, VESPRO can reproduce any workplaces from user defined maps which can be created by means of very common softwares such as Google Sketchup. The so-created maps reproduce faithfully the workplace they are related to including the position of objects to be used in case of emergency. Objects and regions of the maps can be suitably labeled in order to specify their features. Objects, for instance, can be labeled as inflammable or graspable or movable while regions can be classified as safe in the case of earthquake. The users can define their own labels and the behaviors related to such labels in an easy way so as to allow the maximum possible adaptability to any workplace.

Different kinds of harmful events (even simultaneous) such as gas leak, fires and earthquakes, whose intensity can be decided by the users, are simulated within VESPRO and other events can be defined by the user. The basic mission of this software is to provide the user with the possibility of experiencing in a virtual world through an avatar the possible emergencies that can occur in the real world, with richness of peculiarities which make this experience as realistic as possible. Therefore the salient effects of these events, which are described more in detail in section 4, are carefully simulated by VESPRO.

VESPRO is a comprehensive tool as it also includes a module for the evaluation of the user behavior within the virtual scenario when facing the modeled emergencies: the user's performance is evaluated in terms of both accomplished tasks and time required for the completion of the list of tasks that are required in each particular situation. During this phase the software can also correct possible mistakes that are committed by the user and suggest the procedures to be applied.

In order to maximize the efficiency in terms of knowledge transmission and comprehension evaluation VESPRO can be logically subdivided into three parts, that are focused on a different aspect of the learning process and can be arbitrary accessed by the user:

- **Lesson** The avatar autonomously moves in the simulated environment and the user does not exert any interaction, while the software describes, by means of detailed texts, sample images, videos and animations, all the safety procedures to be performed in case of the selected events. All the exit paths are shown together with security exits, while the use of useful objects that are eventually present on the scene is depicted together with the correct code of conduct.
- **Practice** The user moves his avatar within the virtual scene, exploiting some objects, acquiring a deeper knowledge of the structure and of the map of the simulated building and obtaining useful information. The exploration of the simulated environment that is performed by the user helps him to keep important information such as the location of the safety tools (e.g. fire extinguishers, torches and other emergency light sources, gas masks, helmets etc..) and relevant points of potential interventions (e.g. valves, control panels, containers of dangerous or flammable materials, etc.) as well as the exit paths, the security exits, the safe areas and many others. Some screen shots showing the virtual environments are shown in figures 1 and 2.
- **Action** The user through his avatar directly operates during the occurrence of one or more emergencies. He has to move within the scenario facing the dangerous situations and performing the tasks that have been described in the previous phases, which can also be listed in their correct order on the screen. The user's capability of coping with the proposed situation is evaluated and a detailed evaluation report is proposed at the end of the test, in order to allow the user to recognise, understand and correct his own mistakes and improve his knowledge and his reactions. This functionality of the software is detailed in section 5.

4 Virtual scenarios and human interaction

The simulation of the events leading to an emergency is important for providing the user with a realistic experience to be lived in the virtual scenario. The richness of details and the faithful reproduction of real situations is fundamental if the software aim is to offer the user a complete set of information of what really happens in the case of particular disasters and to provide him with a practice that will be fruitful in the case of actual emergency. Within the presented simulator particular attention was paid to these aspects.

The current version of VESPRO includes the simulation of three very common disasters which can take place

Fig. 1 Screenshot showing the realized virtual environment and the avatar

Fig. 2 Screenshot showing the realized virtual environment and the avatar

Fig. 3 A sample screenshot of the software while in *action* mode

on the workplace with regrettably consequences: earthquake, fire and gas leak. These kinds of events are currently part of the events the workers are trained to face during safety courses worldwide. Moreover, thanks to the modular nature of VESPRO, it is possible to add more configurable events or to modify the effects of the already included ones. The events in the simulation phase can occur at the same time and with different intensity on the basis of user decision.

In the design of the disaster particular attention was given to the simulation of the effects of the disasters both on the environments and the avatar: the damages induced by an earthquake can prevent the access to whole parts of the structure and alternative paths toward the exit need to be found, in the meantime, the electrical system can be damaged and, in case of electrical light, the user will need to use and/or find alternative light sources. Similar situations can occur in presence of fire: the smoke limits the visibility and affects the reactivity of the avatar, moreover fire can propagate inside the building to both normal and special flammable objects, which on their hand generate more smoke and flames.

The intensities of each disaster determines the intensity of its effects on the avatar and on the environment. The more intense the fire is, the more rapidly it propagates, the greater the quantity of generated smoke will be. The quantity of smoke affects in an inverse way the the maximum time the avatar can remain in the area interested by the smoke itself. The intensity of an earthquake determines the extension of safe zones where the avatar can take refuge. Figures 7, 8, 9 show the virtual representations of earthquake, gas leak and fire respectively.

The so-designed virtual world can be explored by an avatar in human form, whose characteristics can be defined by the user and can be different for each user of the tool. The characteristics which can be tuned do not only include the physical aspect of the avatar but also its physical parameters and status such as speed, strength and others for the maximization of the realism. The result is a very faithful interaction of the user with the virtual scene by means of the avatar which is controlled through the mouse and the keyboard, such as in many commercial games. Once introduced in the scene, the user can visualize the scene such as it is reported by a video-camera positioned behind the avatar (see for instance figures 1 and 2), in order to allow a good visibility of the avatar itself and of the surrounding scene. Alternatively, the user can choose to have the same field of view as the avatar has (such as depicted in figure 3), by thus enhancing the avatar's exploration capabilities as well as the realism of the virtual experience, as one can turn the avatar's head independently on the rest of the body, by thus changing the field of view.

A wide set of actions has been simulated for the movement of the avatar: walking, rotating, moving sideways and running can be performed and combined. The higher the speed and complexity of the avatar, the more inaccurate its control, such as it happens in the reality; furthermore the accuracy of the user's control of the avatar can be affected by the surrounding environment, for instance by some objects on the ground, the quakes, the presence of fire and smoke.

The avatar can interact with many objects that are present in the scene or can be collected during the simulation and which can be useful to accomplish the security procedures. In particular the avatar can, in an intuitive way, open and close doors and windows, pick up and release objects, operate light switches, electrical panels and alarms, open and close the gas valves. The avatar can, for instance, exploit a torch to illuminate the surrounding environment (it is fundamental, as in certain extreme situations the electrical system can

Fig. 4 A screen shot of the *map mode* which shows how the structure of the building is reproduced and main objects are put into evidence.

be damaged and the rooms of the building are dark), use the fire extinguisher to stop a fire, wear safety helmets, fire blankets or gas masks to move safely in the building.

During the practice and action mode the user can get information on the building by means of the *map mode* which allows the exploration of the building map with a number of detail involving the safety paths, the exits and the location of the safety tools. A sample screenshot of the map mode is shown in figure 4. In the map mode, the user can move through a map of the building and zoom in/out in order to get the information he is looking for. The importance of the map is fundamental within this software, as it provides the user with the opportunity of globally exploring the structure of the building spotting useful objects, pathways and so on and it is a really useful support for the memorisation of the correct path to reach a particular location or a particular objects. This is a fundamental information, for instance, for a user who accesses for the first time or only occasionally to the considered building or industrial plant. For this particular kind of users, specific areas can be highlighted, such as the areas of interest or, one the other hand, the zones where access is not allowed for external personnel.

Moreover, the user can exploit a smaller version of the map located in the upper right corner of the standard window, as a support to the navigation in the virtual environment (see, for instance, figures 1, 2, 3, 7, 8 and 9): the position of the avatar can be followed, such as in the map mode, and all the other relevant objects and areas are visualised in an effective way.

A further source of information on safety measures is constituted by objects themselves, by means of a rich multimedia content which is bound to most of them. The user in facts can easily access to these contents when the avatar is located in proximity of an object which is highlighted by a *i-labeled* balloon, as it is shown in figure 5. For each type of object a multimedia resource has been created. The main page of the resource describes in detail the object and its usage as depicted in figure 6. Subsequently, from this page the user

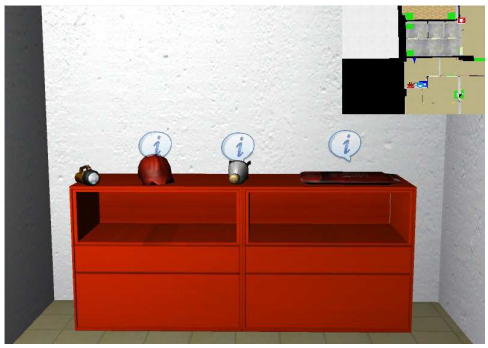

Fig. 5 The balloons which signal the presence of multimedia contents related to an object.

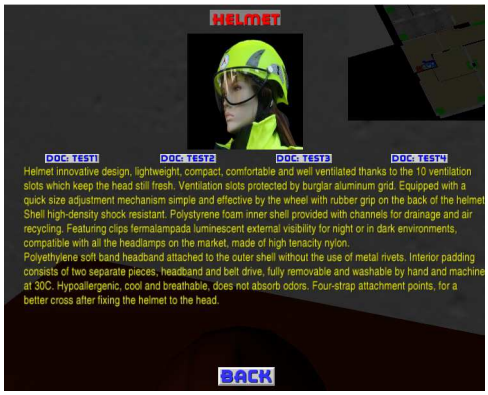

Fig. 6 A sample screen showing the information provided by the main page of multimedia content: information on the object are provided and links to additional contents are highlighted.

can get further access to different multimedia contents, which can include links to web pages, documents, documentary films, animations, images and are fully defined by the scenario creator. Multimedia contents are offered to the users in an interactive way: in facts information about an object can be obtained by finding the object and *asking* for them and the user navigates autonomously the ensemble of information the software can provide him.

5 Emergency simulation and user performance evaluation

The main aim of the VESPRO tool is twofold: on one side there is the teaching of the safety measures and correct behaviors in case of emergency situation; on the other one the evaluation of the user's comprehension. In the emergency simulation mode, one or more of the implemented disasters occur and the user is asked to put into practice the learnt safety procedures by exploiting the knowledge acquired about the building structure and the practice with the objects on the scene. Thus this stage is logically supposed to follow a previous phase of learning and practicing.

Although many tasks are shared among the different

Fig. 7 The visual representation of a earthquake during a session of the software. Screen shakes and powder is visualized on the screen.

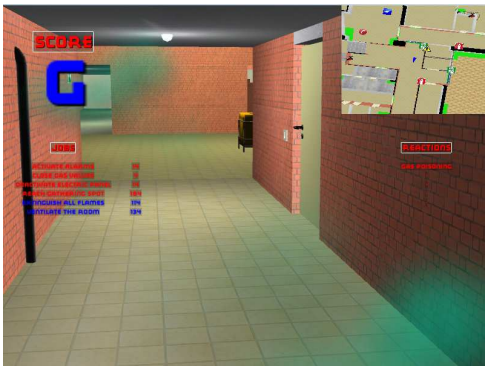

Fig. 8 The visual representation of a gas leak during a session of the software. Gas is respresented as a green cloud.

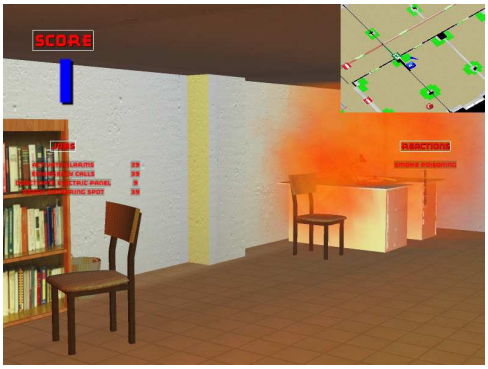

Fig. 9 The visual representation of a fire during a session of the software. Both flames and smoke are represented and their behavior is simulated.

typologies of events, each safety procedure needs the completion of different actions, which also vary depending on disasters intensity and possibly in the case of their combination. Within this framework, the behavior of the user/avatar is assessed in terms of completed operations and an evaluation of his performance is drawn up.

When facing the disasters, the avatar has to carry out several actions which can be classified into two main categories: *tasks* and *reactions* [1]. A *task* is an operation that must be executed during the emergency situation at a precise moment (and in a precise order with respect of other tasks) and/or within precise time constraints. Some examples of tasks that can be required to the user are to operate the general alarm; to call a suitable emergency number; to extinguish the fire; to close some gas valves; to aerate the rooms; to activate or deactivate the electric lightning. The task that are assigned to the user can also depend on its profile: an occasional visitor of the building or plant can be provided with simpler and more fundamental tasks, such as protect himself and eventually extinguish a fire, while a stable worker can be asked to operate more complex tasks, such as operate on control panels and valves. On the other hand, a *reaction* is an action that is executed in response to particular and possibly unpredicted events. Example of reactions are: to escape from fire or from smoky rooms; to reach safe zones when an earthquake is occurring. The harmful effect of smoke, gas and fire can be counteracted by the use of the suitable tools, such as gas masks of fire blankets.

VESPRO provides the possibility to evaluate the user's level of ability by performing some tests. The level of difficulty of the tests can be decided by the user (or by an eventual teacher) and tuned according to its profile or can be automatically set. During the test, the user has to fulfill all the tasks, possibly in the correct order and within a fixed time limit. During the simulation all the required tasks and reactions are visible on the screen to the user (in different colors, in order to distinguish them) together with their time limits (this option can be switched off). If the user fails in one of this tasks and/or in following the correct sequence of required actions, his performance decreases. Performance decrease are also previewed if an expected reaction is not executed, such as, for instance, moving away from a fire or leaving a room in presence of toxic gas. The performance rating algorithm is very simple: at the beginning the user's rating is maximum, i.e. A, and each time a task is not executed within the pre-fixed time interval or unproper reactions are showed by the user, his rating decreases to B, C, etc... up to the minimum rating, that is Z, and the decrease is proportional to the seriousness of the erroneous actions. At the end of the simulation, the user receives a report. This report (an example is shown in figure 10) contains the evaluation of the performance on the emergency simulation and provides details of each erroneous action that was made during the test.

6 Conclusions and future work

In this paper a software for education on safety procedures on the workplaces based on a 3D simulation environment is proposed. The advantages of this approach by respect to more traditional ones (books, videos, etc) consist in the adaptability of the tools to the different exigences of the companies, on the appeal the software generates on the users and on the realistic experience it can provide which are discussed in the paper. The VESPRO tool in facts exploits a realistic virtual envi-

Fig. 10 The report which is presented at the end of the simulation. Evaluation of user's performance is shown together with a list of completed and uncompleted tasks.

ronment for the transmission of a detailed full multimedia knowledge and the complete involvement of the user whose behavior in case of emergency can be subsequently evaluated in the same virtual scene where the training takes places, in order to assess his level of comprehension of the safety procedures as well as of memorisation of the main features of the simulated building.

Presently VESPRO has been customised on a building hosting the authors' research laboratory, but it could also be adapted to other public environments as well as to industrial plants.

The current version of VESPRO has been tested on a sample group of workers and it improved the memorization capabilities of the testers concerning the salient tasks to be performed, the structure of the building, the positions of objects which can be used in the case of emergency, the location of security exits and the exit paths. From this point of view VESPRO results more efficient and complete than traditional methods used.

VESPRO was designed to be easily expandable by adding new types of emergencies, multimedia contents, objects and events; moreover all the maps used by the tool can be created by means of standard software.

In the future further events will be modeled and the use of more objects will be implemented in accordance with different kinds of buildings and workplaces.

Moreover, the interaction of the user with other people present on the scene and eventually needing help, as well as the interaction of two or more users is currently under investigation.

7 References

[1] Vannucci, M.; Colla, V.; Avigni, A.; Avigni A.; *VESPRO: a virtual environment for practicing safety procedures*, Proc. of the 1st International Conference on Information Society and Information Technology, Novo Mesto (Slovenia), October 12-13, 2009, pp.136-141.

[2] Lutz, Mark. *Programming Python, Second Edition*, O'Reilly Media, March 2001

[3] Gutschmidt, Tom. *Game Programming with Python, Lua, and Ruby*, Course Technology PTR; 1 edition, December 1, 2003.

[4] Zayas Perez, B.; Marin, M.M.; Perez, E.I.; *Developing a Virtual Environment for Safety Training Electronics*, Robotics and Automotive Mechanics Conference, 2007. CERMA 2007, 25-28 Sept. 2007 Page(s):545 - 550

[5] Chin-Teng, L.; I-Fang, C.; Shaw-An, L.; Feng-Yu, S. *Multipurpose virtual-reality-based motion simulator* Proceedings of the 3rd World Congress on Intelligent Control and Automation, Volume: 4, 2000.

[6] Philbin, D.A; Ribarsky, W.; Walker, N. and Hubbard, C. *Training in virtual environments: analysis of task appropriateness*. In proc. Of VRAIS'98. Atlanta, 1998.

[7] Regian, M; Shelbilske, W and Monk, J. *A preliminary empirical evaluation of virtual reality as an instructional medium for visual-spatial tasks*. Journal of communication, 42(4), 1992, pp. 136-149.

[8] Moshell, J; Hughes, C. *Virtual environments as a tool for academic learning*. In K.M.Stanney (ed), Handbook of virtual environments: design, implementation and applications. (pp. 893-910), Mahwah, NJ, USA: Lawrence Erlbraum associates, 2002.

[9] Winn, W. *Virtual environments in maintenance training*. In G.Pahl eds. Maintenance training. New York, USA: Springer-Verlag, 1997.