CONTRIBUTION TO THE REQUIREMENTS ENGINEERING OF VIRTUAL ENVIRONMENTS

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Abstract: This paper aims at contributing to the requirements engineering of virtual environments. Requirements engineering is characterized by a process composed of the phases of elicitation, specification, and evaluation, based on concepts from the software engineering area and on experience obtained through the development of virtual environments. The requirements engineering process is described and exemplified and the main conclusions are pointed out.

1 INTRODUCTION

Virtual Reality (VR) is an advanced interface technology that enables the user to use the software system as well as to perceive himself/herself inside of the three-dimensional computer generated environment. In this context, the user can explore the virtual environment, what is made possible through navigation, interaction and immersion techniques (Vince, 2004).

Like for any software system, it is necessary to define the virtual environment requirements appropriately. However, the VR area is still very recent, and does not count on enough studies on requirements engineering for virtual environments and applications. (Kim, 1999). The need to better understand and specify the requirements of such applications motivated this work.

This article intends to contribute for the requirements engineering of virtual environments. A process is presented, defined with basis on concepts from software engineering and complemented by contributions from experiences obtained through the development of several virtual environments.

Section 2 summarizes virtual reality and requirements engineering concepts; section 3 details the requirements engineering process, applied to the development of virtual environments; and the conclusions are presented in section 4.

2 CONCEPTUAL FOUNDATIONS

2.1 Virtual Reality and Virtual Environments

Virtual reality is a strong tendency in human-computer interfaces (Myers, 1996). It is a technology able to provide to the user immersion, navigation and interaction in a three-dimensional computer generated environment, using, for that, multi-sensorial channels as vision, touch and audition (Stuart, 1996; Vince, 2004). Besides the keyboard and mouse, the user can use special devices as gloves, head mounted displays, space balls, joysticks, etc., that generate a "presence" sense, which is a very important requirement of virtual environments. Those devices, associated to techniques and computer languages, make possible the user to interact with the application, allowing the exploration of the virtual environment and the modification of objects in an easy and fast way - for instance, showing, dragging, rotating and visualizing objects under different view points.

An environment represents a certain space and situation, including all its components, conditions and objects. A virtual environment is an interactive environment, generated by computer in a VR system (Kirner; 1999; Kirner 2001).

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2.2 Requirements Engineering

Requirements represent the software system needs and the constraints imposed on it. A requirement is a condition or necessary capacity for a user to solve a problem or reach an objective, concerning the problem domain. Requirements engineering involves the universe of information that compose the system and all its stakeholders (Sommerville, 1997).

Requirements engineering is an essential phase of the software system development process, that comprises a complete definition of the external behavior of the system, in terms of functional and nonfunctional requirements. Several studies have been pointed out that the inadequate definition of requirements is responsible for a significant part of defects in the software. The elimination of these defects becomes more and more difficult and costly as the software development process goes to its subsequent phases of project and implementation (Kirner, 1996).

The main phases of requirements engineering are: elicitation, specification, and validation (Castro, 1995; Kirner, 1999). Such phases will be summarized in the next section.

3 REQUIREMENTS ENGINEERING PROCESS FOR VIRTUAL ENVIRONMENTS

The process here described is based on software engineering concepts (Sommerville, 1997), which were adapted and complemented from a series of lessons learned through the development of various virtual environments, including those presented next.

- VE-Museum (Virtual Environment of Museum). It was developed to represent a Historical Museum, which is a cultural place for public visitation. This place has collections of objects and historical information (Kirner, 1999). Figure 1 presents a view of that museum.

- VE-Capoeira (Virtual Environment of Capoeira). It was developed as part of a collaborative virtual environment for educational purposes, implemented as a distributed, multi-user system (Kirner, 2001). Figure 2 shows a scene modeled for the VE-Capoeira.

- VE-Engineerig (Virtual Environment for Engineering). It was developed to give support to the remote use of a Coordinate Measuring Machine (CMM), used in the construction of high precision mechanical parts (Calonego, 2004). Figure 3 illustrates the MMC, in a virtual reality scenery.

Figure 1: Virtual Museum.

Figure 2: Capoeira Scene.

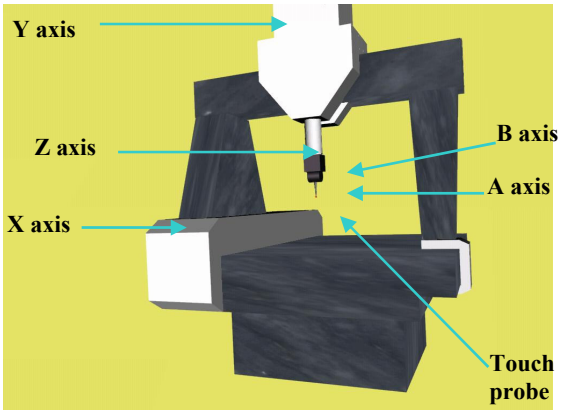

Figure 3: Coordinate Measuring Machine.

3.1 Requirements Elicitation

The elicitation phase involves actions that aim to capture and register information that will help in the complete and correct understanding of the user needs and expectations (Castro, 1995; Sommerville, 1997). The requested tasks can become complex, since the stakeholders have experiences, knowledge, previous concepts and different terminologies.

For the three considered virtual environments, requirements elicitation applied techniques traditionally used in the development of other types of applications, such as: observation, interviews, meetings, besides the identification and analysis of pertinent documentation. In this context, three elements were focused: the potential system users, the tasks to be performed, and the system environment.

3.1.1 System Users

There are several considerations regarding a system user, among which it can be mentioned: if the application will be mono-user or multi-user; if the users will stand at their place or remotely; and if the users will be experts or novices, in terms of use of virtual reality applications.

For the VE-Museum, the users were any people interested to know the place. Therefore, the system should be user-friendly to allow the user not to get lost in the system actions. The actions and the people's interactions were observed in the real environment of the Museum, along with interviews that were performed with employees and the studying of the history of the city. The virtual environment was built as a mono-user system.

The VE-Capoeira theme was selected by the users, children and teenagers. Besides, as the objective was to create a collaborative environment, to work in a distributed platform, it was necessary to identify types of avatars (virtual objects that represent the users) representative of the theme and also attractive to the users.

For the VE-Engineering, the users were students, teachers, and engineering researchers, working in projects for production of specific mechanical parts. Given the specificity of the subject, it was identified the need to train the users for an appropriate and efficient use of the virtual environment.

In the three mentioned environments, the requirements elicitation involved a meticulous exploration and observation of the real environment. For the VE-Museum, there were taken pictures and measurements of the whole environment and of objects that composed it; for the VE-Capoeira, besides pictures, there were developed texts, films, music, etc.; for the VE-Engineering, the configuration and operation manuals were studied. That explained the location of the objects in the real world and also showed details of the floors, walls and illumination, which would help the future construction of the virtual environment objects.

3.1.2 System Tasks

In the requirements engineering phase, it is essential to define the goals of the application, the necessary tasks to reach those goals, and how the tasks will be accomplished in the system.

For the VE-Museum, it was defined that it would be a replica of the real museum. Therefore, it was modeled with the higher level of realism possible. The tasks that should be accomplished by the users are to "walk" around the environment, visit the rooms of the Museum, sign the visitors' book, consult data regarding the collection of available objects, etc. Those tasks should be performed through a workstation, in a mono-user platform.

For the VE-Capoeira, the theme “Capoeira” was chosen and approved by most of the users. Consequently, it was necessary to identify the main tasks that the users could accomplish, besides simply to "walk" in the environment. For this, there were identified and studied the main Capoeira poses that would be implemented later through graphic modeling and animation techniques.

For the VE-Engineering, the level of realism of the Coordinate Measuring Machine was fundamental so that the users could accomplish the foreseen tasks of modeling the parts. It was also essential to understand the correct operation of the machine, including the complete domain of all movements and the commands for triggering those movements.

3.1.3 Application Environment

The application environment can be defined by several ways, as the physical environment, the working environment and the social environment. For virtual environments, the definition of the physical environment in which the system will work deserves special attention. It is important to highlight that the physical environment can represent the real environment with realism or create an imaginary representation of the reality.

For the VE-Museum, the physical environment constituted a replica of the museum, based on the modeling of the rooms, the representation of the

objects, and the drawing of the floor plan of the building.

For the VE-Capoeira, there were identified typical places of Capoeira games, as streets and squares of Bahia, that were represented as sceneries in the virtual environment.

For the VE-Engineering, it was created a scenery representing a laboratory, not necessarily similar to the real laboratory in which the machine was put.

3.2 Requirements Specification

3.2.1 General Functional Requirements

This specification aims to represent the requirements by conceptual models (textual or in a graphic notation) which describe the components and the behavior of the intended software system.

The functional specification of the three considered virtual environments were prepared in Unified Modelling Language (Rational, 2006), supported by the Rational Rose software (Fowler, 1997). Figure 4 shows a use case diagram prepared for the VE Museum.

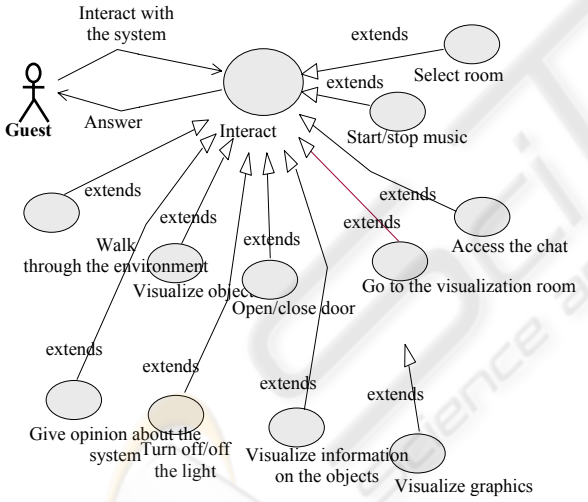

Figure 4: Use Case Diagram for the VE Museum.

3.2.2 Specific Functional Requirements

When a virtual environment is being developed, it is important to consider three possible alternatives, which interfere on the functional specification (Stuart, 1996):

- Alternative 1. When the virtual environment will reproduce tasks performed by users in a real environment and the intention is to show this situation the way it is.
- Alternative 2. When the users carry out certain tasks in the real world, but the virtual environment will reproduce such tasks differently that they happen.
- Alternative 3. When the intended virtual environment will comprise the accomplishment of tasks and interactions that are not carried out in the real world.

In the VE-Museum, there was observed the occurrence of the three situations indicated above. Through the elicitation process, there were verified the tasks that should be accomplished in the same way that the real environment, such as to walk in the environment, open and close doors, turn on and turn off lights, visualize pictures and objects, sign the Visitors' Book, etc. Besides, it was defined the inclusion of some tasks in the virtual environment that could not be executed in the real world, such as to change rooms without moving through the floor plan of the museum. In addition, other tasks of the real environment were also executed in the virtual world, but in a different way, such as to visualize information through graphs placed in a walk-through environment.

In the other two considered virtual environments, there were also defined similar requirements to those defined for the VE-Museum, for subsequent project and implementation.

3.3 Nonfunctional Requirements

3.3.1 General Nonfunctional Requirements

Nonfunctional requirements are related to software aspects, hardware characteristics or external factors, which determine conditions or constraints to the behavior of the intended system. Among these requirements, it is important to point out the following ones (Kirner, 1996; Sommerville, 1997):

- Performance. It is usually related to the fulfillment of processing demands, response time, resource utilization, throughput and efficiency of system processes.

- Usability. It comprises the fulfillment of criteria related to understanding and easiness of use of the system and level of the user satisfaction with the system.

- Security. It concerns the probability of the system in defending itself from accidental or intentional attacks, that can occur through

improper access, denied use, and partial or total destruction.

- Reliability. It is associated to the ability of the system to behave in accordance with what was previously specified, during a certain period of time and with the foreseen resources.

- Other requirements, as portability, maintainability, accessibility, etc. (Kirner, 1996; Sommerville, 1997).

Virtual environments need to fulfill nonfunctional requirements, which should be clearly specified.

In the three focused virtual environments, special attention was given to usability issues. The increment of usability was seek, from the requirements engineering phase, by the identification of ways to make the navigation and interaction easy and fast, such as: forecast of previously defined routes to optimize the exploration and walk-through in the environment; easiness of alteration of view points by the user; inclusion of explanatory texts; definition of clear metaphors; identification of techniques and software for editing images and modeling objects, aiming to build graphic scenes that do not interfere on the system response time to the user interactions.

The explanation of other nonfunctional requirements, specified for the three considered virtual environments, can be obtained in (Calonego, 2004; Kirner, 1999, Kirner, 2001).

3.3.2 Specific Nonfunctional Requirements

Besides the quality aspects stressed in the previous sub-section, virtual environments have peculiarities that demand the accomplishment of additional nonfunctional requirements (Stuart, 1996; Vince, 2004). In this sense, it is expected that a virtual environment can be:

- Synthetic. It means that the virtual environment should be generated in real-time by the computer system, which does not happen with multimedia systems, in which the presentations are previously recorded before they are executed.

- Tri-dimensional. It means that the physical environment that surrounds the user should be modeled in three dimensions, and that the user can walk around that environment.

- Multi-sensorial. It means that the environment should include resources to stimulate different human senses, as vision, audition, touch, space sense, depth, etc.

- Immersive. It means that, besides visualizing the scenes and hearing the sounds, the user should have the impression that he/she is really inside the virtual environment.

- Interactive. Such a requirement makes possible the detection of stimulus sent by the user and, instantly, the promotion of actions capable to modify scenes and objects in the virtual environment.

- Realistic. It refers to the level of precision and conformity that the virtual environment presents compared to the representation of the real world.

- With presence. It is characterized by a subjective sense that the user is physically inside the virtual environment and, many times, participating actively of this environment.

4 REQUIREMENTS EVALUATION

The objective of the evaluation is to assure that the specification really represents the problem domain and the user needs. It is important, in this phase, that the stakeholders that participated in the previous phases are also involved, so that it is possible to make the validation and verification of the requirements described (Castro, 1995).

A series of techniques exists for evaluation of the quality of the requirements, including those that are associated directly to virtual reality applications.

For the three considered virtual environments, the requirements evaluation, in general, was performed in an informal way, through consultations to several people. Such approach of continuous evaluation was facilitated because the systems had been developed following a prototyping approach.

Among the three analyzed virtual environments, the only one which was systematically evaluated concerning its usability characteristics was the VE-

Capoeira. For this, an heuristic evaluation was performed, involving two usability specialists and including the participation of students. This evaluation identified some deficiencies, such as: difficulty on operating some navigation commands; use of technical language, in certain screens; inadequate organization of graphic objects that compose the user libraries.

Based on the evaluation results, a plan of usability improvement for the VE-Capoeira was prepared.

5 CONCLUSION

This work focused on requirements engineering, a critical phase of software development, aiming to contribute specifically for the elicitation, specification and evaluation of virtual environments requirements. The requirements engineering process for virtual environments was outlined, taking into account the concepts originating from the software engineering, complemented by the experience obtained through the development of three virtual environments: VE-Museum, VE-Capoeira, and VE-Engineering.

Several improvements would be necessary in the considered virtual environments, mainly relating to the evaluation of these systems.

The experience in the development of these virtual environments made possible to identify a series of needs, that could be fulfilled through the investment in research related to topics as those related as follow.

- Definition of taxonomies for the categorization of virtual environments, that could be adopted in studies of existing and potential environments.
- Use of methods for elicitation, specification and evaluation of requirements, that were compatible with the peculiarities of the different types of virtual environments. New techniques and languages of specific purpose, that could facilitate the identification and representation of characteristics related to the tri-dimensional representations (including requirements of color, light, scale, point of view, animation, etc.), would be very useful.
- Empirical studies for the investigation of nonfunctional requirements for virtual environments, with emphasis on usability aspects, mainly those related to aspects of use of browsers and special devices, as gloves, glasses and head mounted displays.
- Empirical studies that investigate the characteristics of potentials users of virtual environments and behavior issues of these users when using the environments. Experience with virtual environments has shown that people behave differently to the interaction, navigation and immersion propitiated by virtual reality applications.

New research will contribute to the progress of the area, offering effective subsidies for the professionals and final users involved in virtual reality environments.

REFERENCES

Calonego Jr, N.; Kirner, C.; Kirner, T.G.; Abackerli, A.J., 2004. Implementation of a virtual environment for interacting with a numeric command machine. In *Proceedings of the 3rd IEEE VECIMS Int. Conference*, Boston, MA, USA, pp. 125-130.

Castro J.F.B., 1995. *Introduction to Requirements Engineering.* Tutorial, JAI/SBC, Canela, RS, Brazil.

Fowler, M.; Scott, K., 1997. *UML Distilled – Applying the Standard Object Modeling Language*. Addison-Wesley, Reading, MA, USA.

Kim, G.J. et all., 1999. Software engineering of virtual worlds. In *Proceedings of the ACM VRST Symposium*, Taipei, Taiwan, pp. 131-138.

Kirner, T.G., Davis, A.M., 1996. Nonfunctional requirements of real-time systems. In *Advances in Computers* (Zelkowitz, M., Ed.). Volume 42, Academic Press, pp. 1-37.

Kirner, T.G., Martins, V.F., 1999. A model of software development process for virtual environments. In *Proceedings of the 2nd IEEE ASSET International Symposium*. Richardson, USA, pp. 155-161.

Kirner, T.G., Kirner, C., Kawamoto, A.L., Wazlawick, R.S., 2001. Development of a collaborative virtual environment for educational applications. In *Proceedings of the ACM WEB3D International Conference*, Paderborn, Germany, pp. 61-68.

Myers, B.A.; Hollan, J.; Cruz, I., 1996. Strategic directions in human-computer interaction. *ACM Computing Surveys*, v. 28, n. 4, pp. 794-809.

Stuart, R., 1996. *The Design of Virtual Environments*. McGraw-Hill, Fairfield, PA, USA.

Sommerville, I; Sawer, P., 1997. *Requirements Engineering: A Good Practice Guide*. John Wiley & Sons, England.

Vince, J., 2004. *Introduction to Virtual Reality*. Springer-Verlag, Germany.

RATIONAL, 2006. *UML*. www.rational.com/uml.