An Intelligent and Adaptive Virtual Environment and its Application in Distance Learning

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Abstract. *Virtual Reality (VR) became an attractive alternative for the development of more realistic and interesting visual interfaces for the user. The environments that make use of RV techniques are refered as Virtual Environments (VEs). Nowadays, the focus of attention has been the integration of Artificial Intelligence (AI) and VEs. The objective is to obtain larger usability and realism from the interfaces, exploring the combination of three-dimensional objects and intelligent entities. The environments that explore such integration are called Intelligent Virtual Environments (IVEs). This paper present an intelligent and adaptive virtual environment, which has its structure and presentation suitable according to users' interests and preferences (represented in an user model) and in agreement insertion, removal or update of contents in the environment. A process of automatic categorization of contents is applied in the creation of content models, used in the spatial organization of the same ones in the environment. An intelligent agent, who assists users during the navigation in the environment and retrieval of relevant information, is presented. In order to validate our proposal, a prototype of a distance learning environment, used to make content available, was developed. The motivation to the development of the environment for distance learning is based on the following grounds: the dynamic essence of this environment type (continuously updating contents); diversity of user models; and the promising use of IVEs, allowing the creation of highly interactive environments, motivating the students and enriching their learning.*

Keywords: intelligent virtual environments, intelligent virtual agents, virtual reality, adaptive interfaces, user modeling, content modeling.

1 INTRODUCTION

Virtual Reality (VR) became an attractive alternative for the development of more realistic and interesting three-dimensional visual interfaces for the user [Teichrieb, 1999]. The environments that make use of RV techniques are refered as Virtual Environments (VEs).

In VEs, according to Avradinis et al. (2000), the user is a part of the system, an autonomous presence in the environment. He is able to navigate, to interact with objects and to examine the environment from different points of view. According to Frery et al. (2002), the three-dimensional paradigm is useful mainly because it offers the possibility of representing information in a realistic way, while it organizes content in a spatial manner. In this way, a larger intuition in the visualization of the information is obtained, allowing the user to explore it in an interactive way, more natural to the human. Moreover, a more effective interaction can be obtained from the adaptation of interface, according to the characteristics of individual users or groups of users. According to Chittaro and Ranon (2002), the capability of (semi)automatically adapting the content, structure, and/or presentation of environment, to address the user's interests and preferences is more and more considered as a key factor to increase user satisfaction.

Nowadays, the focus of attention has been the integration of Artificial Intelligence (AI) and VEs. The objective is to obtain larger usability and realism from the interfaces, exploring the combination of three-dimensional objects and intelligent entities. According to Aylett and Luck (2000) and Aylett and Cavazza (2001), the environments that explore such integration are called Intelligent Virtual Environments (IVEs).

An IVE is a virtual environment resembling the real world, populated by autonomous intelligent entities capable of a variety of behaviors. These entities may be simple, static or dynamic objects, virtual representations of life forms (virtual animals and humans), avatars of real world users entering the system, and others [Anastassakis et al. 2001]. According to Rickel et al (2002) and Gratch et al (2002), the potential applications for these environments is substantial, since they could be applied in an array of areas, mainly related to simulations, entertainment and education. Among the possible applications, the 3D chat rooms[1], the

[1] Active Worlds: http://www.activeworlds.com

virtual stores[2] [Chittaro and Ranon, 2002a], the curses of training [Avradinis et al. 2000] and the telemedicine [Nigel et al. 2000; Pletcher et al. 2000] can be quoted.

This paper present an intelligent and adaptive virtual environment, which has its structure and presentation suitable according to users' interests and preferences (represented in an user model) and in agreement insertion, removal or update of contents in the environment. A process of automatic categorization of contents is applied in the creation of content models, used in the spatial organization of the same ones in the environment. An intelligent agent, who assists users during the navigation in the environment and retrieval of relevant information, is presented. In order to validate our proposal, a prototype of a distance learning environment, used to make content available, was developed. The motivation to the development of the environment for distance learning is based on the following grounds: the dynamic essence of this environment type (continuously updating contents); diversity of user models; and the promising use of IVEs, allowing the creation of highly interactive environments, motivating the students and enriching their learning.

The paper is organized as follows. In section 2, the user modeling is commented. Section 3 presents the approach in modeling content. Section 4 comments on related works with IVEs and intelligent agents. In section 5, the proposed intelligent and adaptive virtual environment is presented. Section 6 comments on the prototype developed to validate the environment. Finally, in section 7, the final considerations and future works are presented.

2 USER MODELING

A user model is an explicit representation of the user's needs, characteristics and preferences. According to Kobsa (1995), it is a collection of information and suppositions on individual users or user groups, necessary for the system to adapt several aspects of its functionalities and interface. The employ of a user model has been showing great impact in the development of filter systems and retrieval of information ([Lieberman, 1995]; [Billsus and Pazzani, 1999]), electronic commerce ([Abbattista et al. 2002]), learning systems ([Self, 1999]) and adaptive interfaces ([Perkowitz and Etzioni, 1998]; [Brusilowsky, 2001]).

The acquisition process and representation of a model is called user modeling. This process constitutes the user modeling methodology and can be described in terms of the following stages: (a) identification of the

[2] http://www.vr-shop.iao.fhg.de/vr-shop/epc.html

purposes for the use of the model; (b) definition of the properties that will compose the model; (c) selection of format to represent the model; (d) definition of data to be collected, methods and techniques used for the collection; (e) collection of data; and (f) representation of the data in an user model.

The identification of the purposes for the use of the model should consider: the tasks carried out by the system; the user's objectives in its use; and the aspects of the system that will be adapted. After that, the properties of the model are defined: specialization (individual or of group), temporal extension (short or long term), type of information (e.g., interests, preferences), among others properties. Next, the format of representation of model is chosen, and the type of data that will be collect is determined, in such a way that relevant properties can be extracted from the user, and finally the methods applied to collect data are selected. The types of data that can be collected are divided into [Adomavicius and Tuzhilin, 2001; Abbattista et al. 2002]: fact data (e.g., name, gender, age, preferences), transaction data (e.g., purchases made, spent amount), navigation data (e.g., visited pages, length of navigation in each page) and demographic data (e.g., address, income and occupation, for instance). The methods to collect data can be divided into two groups [Pazzani and Billsus, 1997; Papatheodorou, 2001]: explicit and implicit. Explicit methods collect information directly from the user, finding his interests, preferences and needs, and are usually carried out through the use of forms. Implicit methods, on the other hand, make inferences by monitoring behavior while the user is interacting with the system. The two methods are accessories to each other, in order to build up a larger set of information about the user [Wasfi, 1999]. Finally, the following stage consist the collection of the data, and the explicit representation of the data collected in a user model.

3 CONTENT MODELING

A content model is a collection of information on the content, used to describe it. Among the possible data, which can be used in description, it can be cited: the category of content (the area of knowledge to which the content belongs), the type of content media (e.g., text, video, hyperlink) and the keywords that characterize it.

The process of content modeling involves the collection of information needed to the elaboration of the model and the representation of the information collected. It, generally, consists of categorizing the content, being carried through, in many systems, manually. However, especially to the textual contents, an automatic text categorization can be adopted, in which is suggested a category to the document, as well as is extracted the set of keywords used to characterize it. In this section, the process of automatic text categorization, applied in the content modeling, will be approached. In this work, from the content model, the spatial position that the content will occupy in the environment is defined.

According to Lewis (1991) and Yang and Liu (1999) the categorization is a technique used to identify the category that determined document belongs, using as base its content. Several approaches have been proposed to the automatic text categorization starting from the application of machine learning techniques (see, e.g., [Oliveira and Castro, 2000][Rizzi et al. 2000]; [Duarte et al. 2002]; [Sebastiani, 2002]). In these approaches, the tools are trained to offer support to decision problems (such as classification), based in training data.

The categorization process is formed by a group of stages: (a) collecting from base; (b) pre-processing; and (c) categorization. The collection from base consists of obtaining the examples to be used for the training and the test of the learning algorithm (classifier). The pre-processing involves, for each example, the elimination of the words, which are considered irrelevant (stopwords, e.g., articles, prepositions, pronouns), the removal of the affix of the words (preffixes and suffixes) and the selection of the most important words, used to characterize the document. In the categorization stage, the learning technique is then determined (decision trees or artificial neural networks), the code of each example is implemented (usually adopting a vector representation, where the words selected as important become vector indexes and the respective values indicate the importance of the word in the document), the learning parameters are defined and the classifier learning is accomplished. After these stages, the classifier can be used in the categorization of new documents.

In the proposed environment in this paper, machine learning techniques are adopt in the categorization process, specially to textual contents, allowing the acquisition of content models, from the extration of the category and the set of keywords that characterizes the corresponding content. For not textual contents (for instance, images and videos), the user is responsible for the manual definition of the model.

4 INTELLIGENT VIRTUAL ENVIRONMENTS

The IVEs have been used in several areas, mainly related to new and advanced forms of entertainment, simulation and education. In these environments, the incorporation of intelligent agents, who act as users' assistants, has received special attention. According to Aylett and Cavazza (2001), the intelligent agents when inserted in virtual environments are called Intelligent Virtual Agents (IVAs). They act as assistants of the users in the exploration of the environment and the localization of information, being able to establish a verbal communication (in natural language, for example) or not verbal (through face movement, gestures and expressions) with the user. They can also execute action in the environment, according to user's requests. In this section, related works in IVEs and IVAs are commented.

The Active Worlds[3] comprises of a group of three–dimensional environments, used for the creation of collaborative spaces, where the user, represented by an avatar, can navigate and interact with other users. Panayiotopoulos et al (1999) present a virtual university, where a virtual guide leads visitors to important places, according to their particular needs for information. Noll et al. (1999) present an intelligent agent whose tasks are to provide information about objects, users and the proper environment and to assist the user in the exploration of the environment. Avradinis et al (2000) present a virtual laboratory, built in VRML (Virtual Reality Modeling Language), to support the teaching of concepts related to Physics, where the student can navigate, manipulate objects and run experiments. Nijholt and Hulstijn (2000) present a virtual theater, where the visitors navigate and interact with agents that have information on shows, musicians and tickets. An agent that acts as sales assistant presenting products for the users, is proposed by Milde (2000). Chittaro and Ranon (2002) present an adaptable, three-dimensional virtual environment that features a virtual store, where users can navigate and get information about products. A virtual laboratory for the teaching of digital systems, where the student can interact with the instruments and electronic components during the execution of experiments, is proposed by Casacurta et al (2002). Chittaro et al. (2003) present a virtual agent that assist the user in the navigation in a three-dimensional virtual environment. From the place or object descriptions of interest to be visited in the environment, the appropriate trajectory is created.

In this paper is presented an intelligent virtual environment that has its structure and presentation suitable according to user model and offers resources to assist in the spatial organization of the information in the environment, from the application of content models. Moreover, an intelligent agent acts as users' assistant during the navigation in the environment and retrieval of relevant information. In the next section, the proposed IVE is detailed.

[3] www.activeworld.com

5 THE INTELLIGENT AND ADAPTIVE VIRTUAL ENVIRONMENT

The proposed environment consists of the representation of a three-dimensional world, developed in Java3D[4] and VRML, accessible through the Web, used to make content available. In the environment, there is support for two types of users: information *petitioner* and information *provider*. The *petitioner*, represented by avatars, can explore the environment searching relevant contents and can be aided by the virtual agent, in the navigation and the location of information. A *petitioner model* is maintained, so that the environment can be adapted according to this model. The *providers*, responsible for the available contents, are aided by the agent to sort out the information and they can explore the environment. The available contents are arranged according to the area they belong (Artificial Intelligence and Computer Networks, for instance) and they have an associated model. Contents, petitioner and provider models are used in the process of adaptation of the environment.

According to the *petitioner model*, the personalization of presentation of contents and of structure of environment is performed. The model contains information about the interests, the preferences and the behaviors of the petitioner. For the collection of the data, used in the composition of the model, the approaches explicit (use of questionnaires) and implicit (monitoring the navigation in the environment and verification of the interaction with the *agent*) are used. A *provider model* also is kept, contending information about it area of interest, obtained through the explicit collection. The models of the petitioner and provider are managed by the *user model manager* module.

The contents added, removed or updated by the provider are managed by the *content manager* module and stored in a *content database*. Each content contains an associated model (*content model*). The *provider*, aided by the automatic text categorization process, acts in the definition of this model.

The representation of the information in the environment is made by 3D components, such as graphic objects and icons, and links to the contents. A module, *environment generator*, is the responsible for the generation of the 3D structures that form the environment, allowing the construction of different environments, according to the user models, and to arrangement of the information in the environment, according to the content model. The adaptation involves the reorganization of the environment, in relation to the arrangement of the contents,

[4] API available in: http://java.sun.com/products/java-media/3D

and aspects of its layout. Besides, this module transmits the agent the applicable information about the user model that is interacting with the environment, and information about the contents and their locations, so that it holds enough information to assist the users.

In the following sections are detailed the main components of the architecture: user model manager, content model manager and intelligent virtual agent.

5.1 USER MODEL MANAGER

The user (petitioner or provider) model manager is responsible for to initialize and to update user models. The user model contains information about the users's interests, preferences and behaviors. For collecting the data used in the composition of the model, the explicit and implicit approaches are used. The explicit approach is adopted to the data acquisition for compouding an initial user model, having been the implicit one applied to update this model. In the explicit approach, a form is used, to collect the following data: name, e-mail, gender, areas of interest and preferences for colors. The three last data are used in the initial adaptation of the environment. In the implicit approach, the monitoring of the user navigation in the environment and the interaction verifications with the agent are made. Through this approach, the places of the environment visited by the user and the requested (through the search mechanism) and accessed (clicked) contents are monitored. These data are used to update the initial user model.

The process of updating the user model is based on the employ of rules and certainty factors (CF) ([Nikolopoulos, 1997]; [Giarrato and Riley, 1998]). The rules, formalism commonly adopted in expert systems for the knowledge representation, allow infer conclusions (hypothesis) from antecedents (evidences). To each conclusion, it is possible to associate a CF, which represents the degree of belief associated to corresponding hypothesis. Thus, the rules can be described in the following format: **IF** Evidence (s) **THEN** Hypothesis with **CF = x**. The CFs associate measures of belief (MB) and disbelief (MD) to a hypothesis (H), given an evidence (E). A factor of certainty 1 indicates total belief in a hypothesis, while -1 corresponds the total disbelief. The calculation of the certainty factor is accomplished by the following formulas:

$$CF = \frac{MB - MD}{1 - MIN(MB,MD)}$$

$$MB = \begin{cases} 1 \quad if\ P(H) = 1 \\ \dfrac{MAX[P(H|E), P(H)] - P(H)}{1 - P(H)} \quad otherwise \end{cases} \qquad MD = \begin{cases} 1 \quad if\ P(H) = 0 \\ \dfrac{MIN[P(H|E), P(H)] - P(H)}{0 - P(H)} \quad otherwise \end{cases}$$

In the environment, the evidences are related to the areas of environment visited and to the requested and accessed contents by the user. The user's initial interest in a given area (initial value of *P(H))* is determined by the explicit collection of data and it may vary during the process of updating the model, based on threshold of increasing and decreasing belief. The evidences are used to infer the hypothesis of the user's interest in each area of knowledge, since the rules and corresponding certainty factor. For updating the model, the follow rules are defined:

IF request
THEN interest in Y with **CF = x** (1)

IF navigation
THEN interest in Y with **CF = x** (2)

IF access
THEN interest in Y with **CF = x** (3)

IF (not request) and (not navigation) and (not access)
THEN interest in Y with **CF = x** (4)

The Rules 1,2 and 3 are used when evidences of request, navigation and/or access exist. In this case, is made the combination of the rules and the resultant CF is calculated (following formula). The rule 4 is especially used when any evidence does not exist, resulting in CF = -1 for the interest in the corresponding area. This rule was added because, in cases where evidences exist, the CF can be less than 0.

$$CF = \begin{cases} CF1 + CF2\,(1 - CF1) & \text{if both} > 0 \\ \dfrac{CF1 + CF2}{1 - MIN\,(|CF1|,|CF2|)} & \text{if one} < 0 \\ CF1 + CF2\,(1 + CF1) & \text{if both} < 0 \end{cases}$$

In each *n* sessions (adjustable time window), for each area, the evidences (navigation, request and access) are verified, the inferences in the rules are made, and the certainty factors corresponding to the hypotesis of interes are verified. By sorting the resulting certainty factors, it is possible to establish a ranking of the areas of interest of the user, therefore it is possible to verify the alterations in the initial model (obtained from the explicit collection) and, thus, to update the user model. From this update, the reorganization of the environment is made.

5.2 CONTENT MANAGER

The content model manager is the module responsible for the insertions, removals and updates of the contents, and for the management of its models. The provider is responsible for defining the content model, being able to be assisted by the automatic categorization process. In the insertion of a content, the provider must inform the following data, used in the composition of the content model: category (among a pre-established set), title, description, keywords, type of media and corresponding archive. To textual contents, the automatic text categorization process is available, thus the category and the keywords of the content are obtained.

The categorization process proposed in this work is based on the use of techniques of machine learning (Decision Trees [Quinlan, 1993] and Artificial Neural Networks [Haykin, 2001]). In this way, the areas (for being contemplated in the environment) had been defined, and collected the examples (base of training and validation), and carried through the pre-processing and the training of the learning algorithm. The pre-processing stage is supported by an application[5] that removes the stopwords and affixes, extracting the main words of each document, and generates the scripts (with the documents properly codified) that are submitted to the learning algorithms. The application, implemented in Java, extended from a *framelet* (see [Pree and Koskimies, 1999]), whose kernel contemplates the basic flow of data among the activities of removal of stopwords and affixes, selection of important words and generation of scripts. From the finishing point of the framelet hot – spots, the activities can be customized according to the needs of the application. Thus, the framelet offers enough flexibility for the generation of different script file formats, which allows the accomplishment of a wide range of experiments, in which the performance of the algorithms can be measured to then select the one that presented better results. In the experiments (details can be obtained in [Santos and Osorio, 2003]), the decision trees resulted more robust and were selected for use in the categorization process proposed for the environment. It must be stressed that in the pre-processing, for the removing the irrelevant words is used the list of stopwords to English language elaborated by the Laboratory of Recovery of Information in Massachusetts University[6]. The adopted algorithm of extration of affixes is the Porter

[5] Framelet available in: http://www.inf.unisinos.br/~cassiats/mestrado.htm
[6] Available in: http://www.cs.umass.edu/Dienst/UI/2.0/Describe/ncstrl.umassa_cs%2FUM-CS-1991-093

stemming algorithm, proposed by Martin Porter[7]. It is a process for removing he commer morphological and inflexional endings from words in English. For selecting the most important words of each document, the algorithm of selection for frequency is used, where the *n* words that more occur in documents of the corresponding category are selected. The tools used for training of the learning algorithm, decision trees and artificial neural network, had been C4.5 [Quinlan, 1993] and Neusim (Neural Simulator [Osorio and Amy, 1999]).

After appling the learning algorithm, the "learned model" – rules extracted from the decision tree – is connected to the module content manager, in order to use in the categorization of new documents. For this, an application[8], implemented in Java, converts the rules extracted from the decision tree to rules of type IF – THEN. Thus, when a new document is inserted in the environment, it is pre-processed, it has its keywords extracted and it is categorized. With the content model, the spatial position, where the content must be placed, is determined.

5.3 INTELLIGENT VIRTUAL AGENT

According to Ballegooij and Eliëns (2001), the three-dimensional virtual environments suffer from problem of users getting "lost in environment". In this context, resources to provide assistance to the user in the navigation for the environment and the localization of relevant information are necessary. Amongst the resources generally used, it can be cited: the identifications of places in the environment (e.g., use of arrows and plates); the maps 2D of the environment; and the virtual assistants. According to Chittaro and Ranon (2003), the introduction of virtual assistants has the additional advantage of making the environment more lively and attractive to the user. In this way, the use of virtual agents who act as users' assistants, has many advantages: to enrich the interaction with the virtual environment [Rickel et al. 2002]; to turn the environment less intimidador and most natural for the user [Chittaro et al. 2003]; to prevent the users from feeling lost in the environment [Rickel and Johnson, 2000].

In the proposed environment, an intelligent virtual agent assists users during the navigation in the environment and retrieval of relevant information. It has the following characteristics: perception of the environment, ability to interact, knowledge and graphic representation. The perception of the environment

[7] Available in: http://www.tartarus.org/~martin/PorterStemmer/index.html
[8] Available in http://www.inf.unisinos.br/~cassiats/mestrado.

represents the agent's observations during the interaction with the user, and its interaction ability is related to the exchange of information with the user. The agent's knowledge is represented by the information that it holds on the user and the environment, which it can be updated during the course of interaction. For instance, if the user requests an information which area is not mapped in his model, the agent adds this request to its knowledge, building a new knowledge for the agent, used later as evidence for the process of updating the model.

The agent's knowledge is stored in a knowledge base built from two sources of information: external source and perception of the interaction with the user. The external source is the information about the environment and the user, and they are originated from the environment generator module. A perception module acts to observe the interaction with the user, and the information obtained from this observation is used to update the agent's knowledge. It is through the perception module that the agent detects the requests to assist in navigation, location and display of information. Based on its perception and in the knowledge that it holds, the agent decides how to act in the environment. A decision module is responsible for this activity. The decisions are passed to an action module, responsible to execute the suitable decisions of the decision module and the manipulation of the agent's graphic interface.

The communication between the agent and the users is made in a verbal way, through a pseudo-natural language, and non verbal way, by the agent's actions in the environment. The dialogue in pseudo-natural language consists of a certain group of questions and answers and short sentences, formed by a verb that corresponds to the type of user request (helping the navigation or the location of given information), and a complement, regarding the object of the user interest. During the request for helping to locate information, for instance, the user can indicate (in textual interface) *Locate* <*content*>, and to ask help to navigate, he can indicate *Navigate* <*area* >. The agent's answers are suggested by its own movement through the environment (moving towards the information requested by the user, for instance), by indications through short sentences, and by text-to-speech synthesis. A synthesizer, developed with standard JSAPI[9], allows that short sentences, presented in a textual interface, are converts to speech. Moreover, it must be emphasited that, in the interaction with the provider, during the insertion of a content, he can indicate *To insert* <*content*>, and the agent presents the interface of entry of the data for the formation of the content model. It is by this interface

[9] http://java.sun.com/products/java-media/speech/index.jsp

that the categorization process can be invoked. As a way to simplify the communication model, the options of questions are available to the user by a mechanism of selection of options.

So that the agent can provide aid to the navigation in the environment and to the localization of information, a topological map of the environment is kept in the base of knowledge. In this map, a set of routes for key-positions of the environment is stored. In accordance with information that it has about the environment (repassed by the environment generator module) and in the topological map, the agent defines the set of routes that must be used in the localization of determined content or the navigation until determined area of the environment. Considering that the agent updates its knowledge to each modification in the environment, it is able to verify the set of routes that leads to the new position of one determined content.

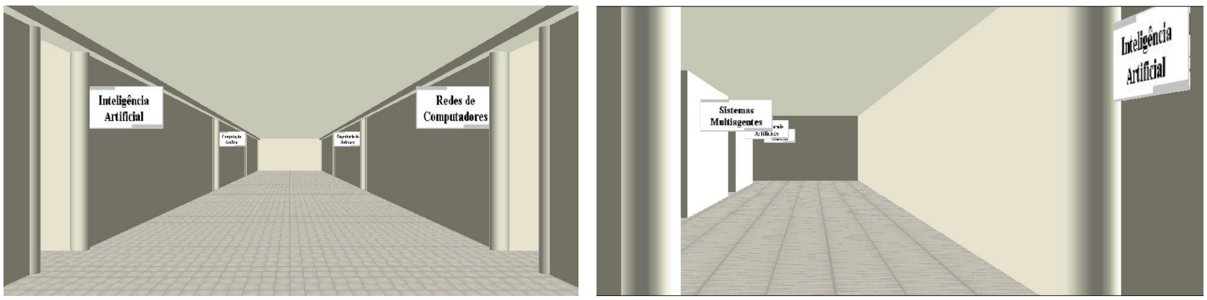
6 THE PROTOTYPE

In order to validate our proposal, a prototype of a distance learning environment, used to make content available, was developed. The motivation to the development of the environment for distance learning is based on the following grounds: the dynamic essence of this environment type (continuously updating contents); diversity of user models; and the promising use of IVEs, allowing the creation of highly interactive environments, motivating the students and enriching their learning.

Nevertheless, the proposed environment can be extended to applications where the combination between user and content models in the process of adaptation of the environment is promising. Among the possible applications, e-commerce aplications can be cited. For instance, the three-dimensional virtual shoppings offer to user a more natural and attractive interaction, so he is able to navigate through a virtual store and visualize products in a more realistic way compared to bi-dimensional interfaces. In this context, the possibility to arrange stores and products, according to the users' preferences and needs (impracticable in a real environment), facilitates the access to products and increases user's level satisfaction. Also, the use of intelligent assistants that establish a dialogue with the users and offer help to the localization of stores or products, or offer information about the same ones, can make the interaction even more interesting.

In the prototype, a division of the virtual environment is adopted according to the areas of the knowledge of the contents. To each area a set of sub-areas can be associated. The sub-areas are represented as sub-environments. To the prototype the following areas and sub-areas were selected: Artificial Intelligence (AI) –

Artificial Neural Networks, Genetic Algorithms and Multi Agents Systems; Computer Graphics (CG) – Modelling, Animation and Visualization; Computer Networks (CN) – Security, Management and Protocols; Software Engineering (SE) - Analysis, Patterns and Software Quality. A room is associated to each area in the environment and the sub-areas are represented as sub-rooms. Figure 1 (a) and (b) show interfaces of the prototype that illustrate the division of the environment in rooms and sub-rooms.

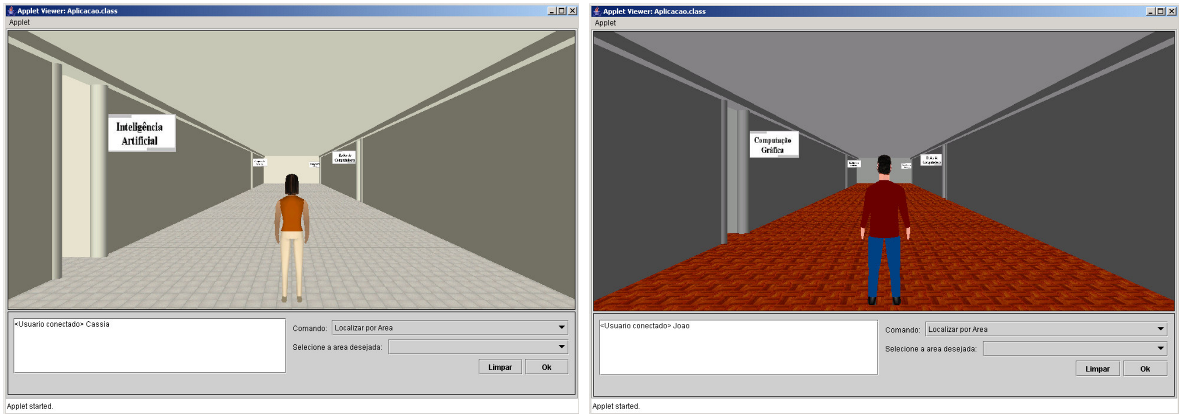


(a) (b)

Figure 1. (a) Rooms of the environment; (b) Sub-rooms of the environment.

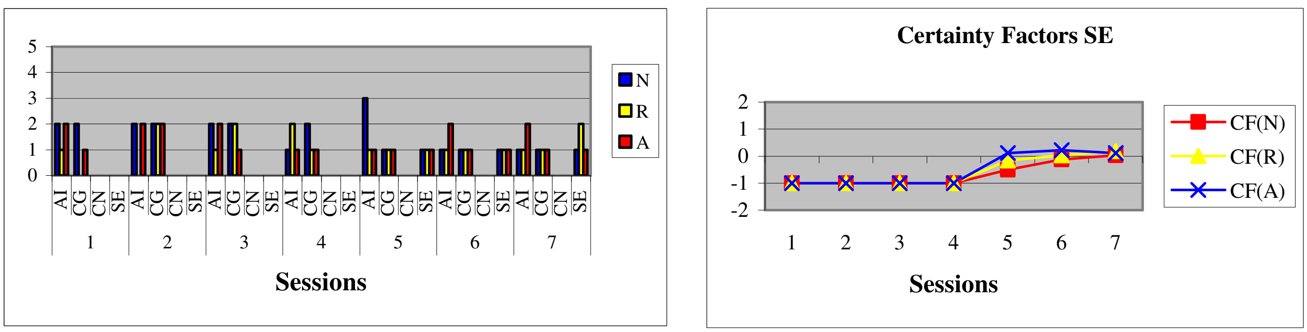
According to the user model, the re-organization of this sub-environment is made: the rooms that correspond to the areas of the user's interest are placed, in a visualization order, before the rooms in which contents are not interesting. This way, the contents that are not interesting are not discarded from the environment, but the ones of interest are emphasized, allowing the user to be free to visualize several contents. The initial user model is used by the initial organization of the environment. As the user interacts with the environment, his model is updated and changes in the environment are made. Figure 2 (a) and (b) represent examples of the initial adaptations of environment. In the environment of Figure 2 (a), the user (female gender) has interest for AI e by use of clean color; in the environment of Figure 2 (b), the user (male gender) has interest by CG and by use of dark color.

After *n* sessions (time window), for each area, the evidences (navigation, request and access) are verified, in order to update the user model. For instance, with an user, who has interest about Artificial Intelligence (AI), is indifferent with the areas of Computer Networks (CN) and Computer Graphics (CG), and does not show initial interest about Software Engineering (SE), the initial values of the CFs, at the beginning of the first session of interaction (without evidences), would be respectively 1, 0, 0 e –1. After giving the navigations (N), requests (R) and accesses (A), presented in the graph of Figure 3 (a), the CFs can be reevaluated.



(a) (b)

Figure 2. (a) User with interest in AI; (b) User with interest in CG.



(a) (b)

Figure 3. (b) Number of navigations, requests and accesses of each area, for session; (a) Certainty factors corresponding to evidences of the SE area.

According to Figure 3 (a), it is verified that the CN area was not navigated, requestes and accessed and since the fourth session, the user started to navigate, to request, and to access contents in SE area. As presented in the graph of Figure 3 (b), an increasing of the CFs had been related by SE area. In that way, at end of the seventh session, the resulting CFs would be 1, -1, 0.4 and 0.2 (AI, CN, CG, SE, respectively). By sorting the resulting CFs, it would be possible to detect an alteration in the user model, whose new ranking of the interest areas would be AI, CG, SE, CN. Figure 4 (a) and (b) represent an example of the organization of the environment before and after a modification in the user model, as example above.

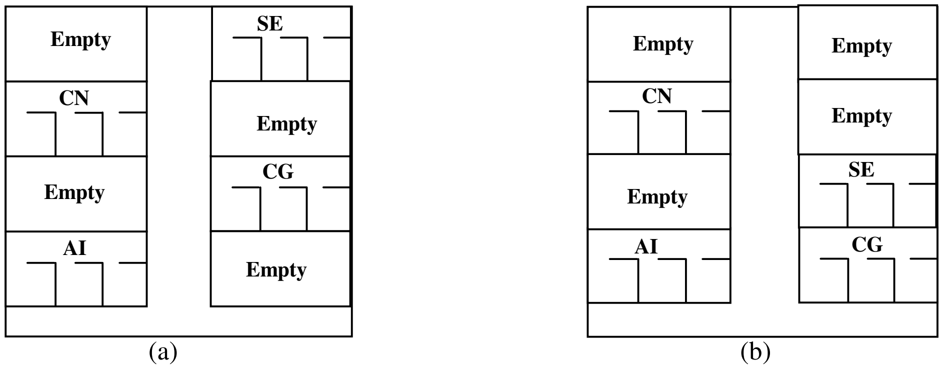


Figure 4. (a) Organization of the environment according initial user model; (b) Organization of the environment after the user model changes.

As the manipulation of contents, the provider model is used to indicate the area (Artificial Intelligence, for instance) that belongs to the content that is being inserted, and the automatic categorization process indicates the sub-area (Artificial Neural Nets, for instance) corresponding, or either, the sub-room where the content will have to be inserted. The spatial disposal of the content is made on the basis of its category, of automatic form for the environment generator. For the prototype, thirty examples, for each sub-area, had been collected, from the mechanism of search in the Web and extracted its abstract, introduction and conclusion (used for learning and validation of the algorithm). In the stage of learning, experiments with binary and multiple categorizations had been carried through. In the binary categorization, a tree is used to indicate if a document belongs or not to the definitive category. In the multiple categorization, a tree is used to indicate the most likely category of one document, amongst a possible set. The table 1 presents the results, indicating the error of generalization (validation base), the number of nodes of the tree, and the measures of recall and precision. The binary categorization presents better resulted (lesser error and, consequently, greater recall and precision), being adopted in the proposed categorization process.

Table 1. Comparative between binary and multiple categorizations.

Area	*Categorization*	*Error*	*Nodes*	*Recall*	*Precision*
CG	Multiple	28,86	14,33	0,71	0,71
	Binary	19,25	8,85	0,78	0,80
SE	Multiple	12,33	7,66	0,87	0,89
	Binary	9,25	6,78	0,89	0,91
AI	Multiple	3,33	5,66	0,96	0,96
	Binary	5,18	5,44	0,94	0,94
CN	Multiple	26,66	13,66	0,73	0,74
	Binary	13,71	9,22	0,86	0,87

As communication between the agent and the users, they interact by a dialog in pseudo-natural language (commented in section 5.3). The user can select the request to the agent in a list of options, simplifying the communication. The agent's answers are listed in the corresponding interface and synthesized to speech. Figures 5 (a), (b), (c) and (d) illustrate, respectively: a request of the user for the localization of determined area and the movement of agent; the localization of an area for the agent; the visualization of a content, for the user; and the visualization of details of a content, from click in content description.

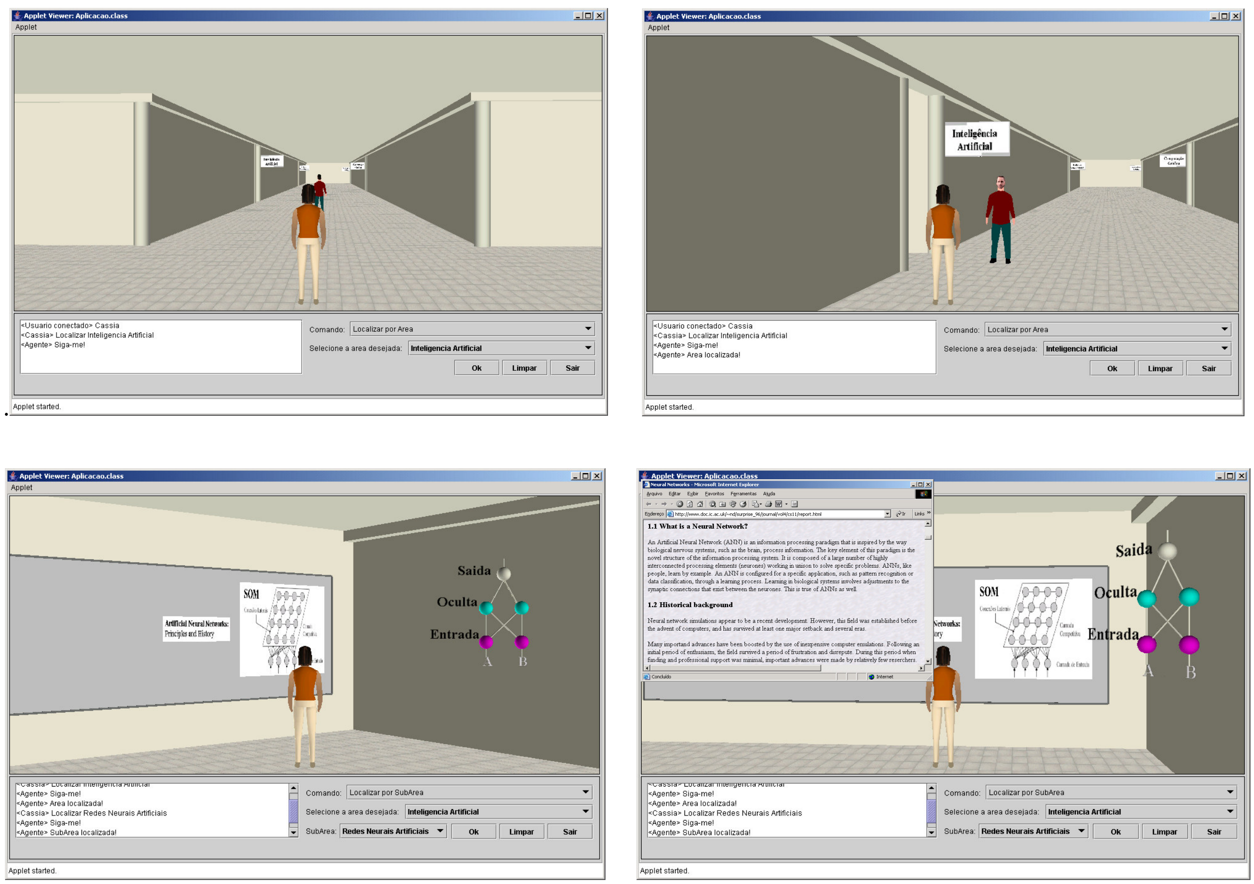


Figure 5. (a) Request of the user to the agent; (b) Localization of an area for the agent; (c) Visualization of contents of ANN sub-area, corresponding to AI area; (d) ; Visualization of details of a content, from click in the content description.

7 FINAL REMARKS AND FUTURE WORKS

A large number of distance learning environments make content available through 2D environments, usually starting from interfaces in HTML, offering little interaction with the user. This paper presented an intelligent, adaptable, three-dimensional and virtual environment that explores the resources of Virtual Reality, seeking to increase the interactivity degree between the users and the environment. The re-organization possibilities and customization of the environment, according to the modifications (addition, removal and updating) in the contents available and the user models were presented. Besides, a automatic categorization process that aims at helping the specialist of the domain in the organization of the information in the environment was shown. Finally, an intelligent assistant that knows the environment and the user and acts assisting in the navigation and location of information in the environment was commented.

Another aspect approached in this work deals with the acquisition of users' characteristics in a three-dimensional environment. Most of the works related to the acquisition of user models and the construction of environments that adapt to these models are approached in 2D interfaces. Finally, a big portion of the efforts in the construction of intelligent virtual environments don't foresee the combination of user models, assisted navigation and retrieval of information, and, mainly, reorganize the environment, and display the contents in the three-dimensional space. Usually, only a sub-group of these problems is approached.

Moreover, the proposed environment could be adapted to support e-commerce applications, allowing to build highly interactive and customizable virtual stores and shopping centers. Another aspect approached in this work deals with the acquisition of users' characteristics in a three-dimensional environment. Most of the works related to the acquisition of models and the construction of environments that adapt to these models are approached in 2D interfaces.

As future works, many possibilities exist. First, exploring the processing of natural language in the process of communication between the agent and the users could be made. Second, the proposal architecture would be interesting to use in an application of e-commerce. Third, the environment could be extended to support the interaction multi-user, and a study of the possibilities of personalization in this type of environment could be carried through.

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