Integrating Intelligent Agents, User Models and Automatic Content Categorization in a Virtual Environment

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Abstract. This paper presents an approach that aims to integrate intelligent agents, user models and automatic content categorization in a virtual environment. In this environment, called AdapTIVE (Adaptive Three-dimensional Intelligent and Virtual Environment), an intelligent virtual agent assists users during navigation and retrieval of relevant information. The users' interests and preferences, represented in a user model, are used in the adaptation of environment structure. An automatic content categorization process, that applies machine-learning techniques, is used in the spatial organization of the contents in the environment. This is a promising approach for new and advanced forms of education, entertainment and e-commerce. In order to validate our approach, a case study of a distance-learning environment, used to make educational content available, is presented.

1 Introduction

Virtual Reality (VR) becomes an attractive alternative for the development of more interesting interfaces for the user. The environments that make use of VR techniques are refered as Virtual Environments (VEs). In VEs, according to [2], the user is 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. As indicated in [11], 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 humans.

Nowadays, the use of intelligent agents in VEs has been explored. According to [3], these agents when inserted in virtual environments are called Intelligent Virtual Agents (IVAs). They act as users' assistants in order to help to explore the environment and to locate information [8,15,16,18], being able to establish a verbal communication (e.g., using natural language) or non verbal (through body movement, gestures and face expressions) with the user. The use of these agents has many advantages: to enrich the interaction with the virtual environment [25]; to turn the environment less intimidating, more natural and attractive to the user [8]; to prevent the users from feeling lost in the environment [24].

At the same time, the systems capable of adapting its structure from a user model have received special attention on research community, especially Intelligent Tutoring Systems and Adaptive Hypermedia. According to [13], a user model 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 information retrieval [4,14], electronic commerce [1], learning systems [29] and adaptive interfaces [5,21]. These systems have already proven to be more effective and/or usable that non adaptive ones [10]. However, the research effort in adaptive systems has being focused in the adaptation of traditional bidimensional/textual environments. Adaptation of three-dimensional VEs is still few explored, but considered promising [6,7].

Moreover, in relation to organizing of content in VEs, the grouping of the contents, according to some semantic criterion, is interesting and sometimes necessary. An approach to organization of content consists in the automatic content categorization process. This process is based on machine learning techinques (see e.g, [28]) and comes being applied in general context, such as web pages classification [9,20]. However, it can be adopted in the organization of content in VE context.

In this paper we present an approach that aims to integrate intelligent agents, user models and automatic content categorization in a virtual environment. In this environment, called AdapTIVE (Adaptive Three-dimensional Intelligent and Virtual Environment), an intelligent virtual agent assists users during navigation and retrieval of relevant information. The users' interests and preferences, represented in a user model, are used in the adaptation of environment structure. An automatic content categorization process is used in the spatial organization of the contents in the environment. In order to validate our approach, a case study of a distance-learning environment, used to make educational contents available, is presented.

The paper is organized as follow. In section 2, the AdapTIVE architecture is presented and its main components are detailed. In section 3, the case study is presented. Finally, section 4 presents the final considerations and future works.

2 AdapTIVE Architecture

The environment consists of the representation of a three-dimensional world, accessible through the Web, used to make content available, which are organized by the area of knowledge that they belong. In the environment (Fig. 1), there is support for two types of users: information *consumer* (e.g., student) and information *provider* (e.g., teacher). The users are represented by avatars, they can explore the environment searching relevant content and can be aided by the *intelligent agent*, in order to navigate and to locate information. The user models are used in the environment adaptation and are managed by the *user model manager* module. The contents are added or removed by the provider through the *content manager module* and stored in a *content database*. Each content contains a *content model*. The *provider*, aided by the automatic content categorization process, acts in the definition of this model. From the *content model*, the spatial position of each content in the environment is defined. The representation of the contents in the environment is made by three-dimensional objects and links to the data (e.g., text document, web page). The *environment generator module* is the responsible for the generation of different three-dimensional structures that form the environment and to arrange the information in the environment, according to the user and content models. The environment adaptation involves its reorganization, in relation to the arrangement of the contents and aspects of its layout (e.g. use of different textures and colors, according to user's preference). In the following sections are detailed the main components of the environment: user model manager, content manager and intelligent agent.

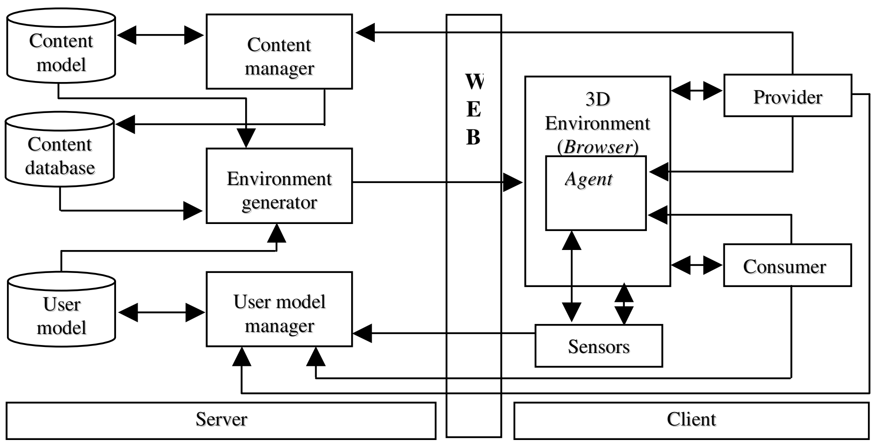

Fig. 1 AdapTIVE architecture.

2.1 User Model Manager

This module is responsible for the initialization and updating of user models. The user model contains information about the user's interests, preferences and behaviors. In order to collect the data used in the composition of the model, the explicit and implicit approaches [19,20] are used. The explicit approach is adopted to adquire the user's preferences compouding an initial user model and the implicit one is applied to update this model. In the explicit approach, a form is used to collect fact data (e.g., name, gender, areas of interest and preferences for colors). In the implicit approach, the monitoring of user navigation in the environment and his interactions with the agent are made. Through this approach, the environment places 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 rules and certainty factors (CF) [12,17]. The rules allow to 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 degree**. The CFs associate measures of belief (MB) and disbelief (MD) to a hypothesis (H), given an evidence (E). A CF=1 indicates total belief in a hypothesis, while CF=-1 corresponds a total disbelief. The calculation of the CF is accomplished by the formulas (1), (2) and (3), where P(H) represents the probability of the hypothesis (i.e. the interest in some area), and P(H|E) is the probability of the hypothesis (H), given that some evidence (E) exists. In the environment, 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), where P(H|E) is obtained from the implicit approach.

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

$$MB = \begin{cases} 1 & \text{if } P(H) = 1 \\ \dfrac{MAX[P(H|E), P(H)] - P(H)}{1 - P(H)} & \text{otherwise} \end{cases} \tag{2}$$

$$MD = \begin{cases} 1 & \text{if } P(H) = 0 \\ \dfrac{MIN[P(H|E), P(H)] - P(H)}{0 - P(H)} & \text{otherwise} \end{cases} \tag{3}$$

The evidences are related to the environment areas visited and to the requested and accessed contents by the user. They are used to infer the hypothesis of the user's interest in each area of knowledge, from the rules and corresponding CFs. To update the model the rules (4), (5), (6) and (7) were defined. The rules (4), (5) and (6) are used when evidences of request, navigation and/or access exist. In this case, the combination of the rules is made and the resultant CF is calculated - formula (8), where two rules with CF1 and CF2 are combinated. The rule (7) is used when does not exist any evidence, indicating total lack of user interest in the corresponding area.

IF request **THEN** interest in Y with **CF = x** (4)
IF navigation **THEN** interest in Y with **CF = x** (5)
IF access **THEN** interest in Y with **CF = x** (6)
IF (not request) and (not navigation) and (not access) **THEN** interest in Y with **CF = x** (where x<0) (7)

$$CF = \begin{cases} CF1 + CF2\,(1 - CF1) & \text{if both} > 0 \\ \dfrac{CF1 + CF2}{1 - MIN(|CF1|,|CF2|)} & \text{if one} < 0 \\ CF1 + CF2\,(1 + CF1) & \text{if both} < 0 \end{cases} \tag{8}$$

Each *n* sessions (adjustable time window), for each area, the evidences (navigation, request and access) are verified, the inferences with the rules are made, and the CFs corresponding to the hypotesis of interest are updated. By sorting the resulting CFs, it is possible to establish a ranking of user's areas of interest. Therefore, it is possible to verify the alterations in the initial model (obtained from the explicit data collection) and, thus, to update the user model. From this update, the reorganization of the environment is made - contents that correspond to the areas of major user's interest are placed, in a visualization order, before the contents which are less interesting (easier access). Moreover, it must be addressed that each modification in the environment is always suggested to the user and accomplished only under user's acceptance.

The motivation to adopt rules and CFs is based on the following main ideas. First, it is a formalism that allows to infer hypothesis of the user's interests in the areas from a set of evidences (e.g., navigation, request and access), also considering a degree of uncertainty about the hypothesis. Second, it doesn't require to know a priori set of probabilities and conditional tables, as it occurs with the use of the Bayesianas Nets, an other common approach used in user modeling. Third, it doesn't require the pre-definition of user categories, as in the techniques based on stereotypes. Moreover, it has low computational cost, is intuitive and robuste. All these aspects are relevant in user modeling.

2.2 Content Manager

This module is responsible for insertion and removal of contents, and management of its models. The content models contain the following data: category (among a pre-defined set), title, description, keywords, type of media and corresponding file. From content model, the spatial position that the content will occupy in the environment is defined. The contents are also grouped into virtual rooms by main areas (categories). For textual contents, an automatic categorization process is available, thus the category and the keywords of the content are obtained. For non textual contents (for instance, images and videos), textual descriptions of contents can be used in the automatic categorization process.

The automatic categorization process is formed by a sequence of stages: (a) document base collection; (b) pre-processing; and (c) categorization. The document base collection consists of obtaining the examples to be used for training and test of the learning algorithm. The pre-processing involves, for each example, the elimination of irrelevant words (e.g., articles, prepositions, pronouns), the removal of affix of the words and the selection of the most important words (e.g., considering the word frequency occurrence), used to characterize the document. In the categorization stage, the learning technique is then determined, the examples are coded, and the classifier learning is accomplished. After these stages, the classifier can be used in the categorization of new documents.

In a set of preliminary experiments (details in [26]), decision trees [23] showed to be more robust and were selected for use in the categorization process proposed in the environment. In these experiments, the pre-processing stage was supported by an application, extended from a *framelet* (see [22]), whose kernel contemplates the basic flow of data among the activities of the pre-processing stage and generation of scripts submitted to the learning algorithms. After applying the learning algorithm, the "learned model" - rules extracted from the decision tree - is connected to the content manager module, in order to use it in the categorization of new documents. Thus, when a new document is inserted in the environment, it is pre-processed, has its keywords extracted and is automatically categorized and positioned in the environment.

2.3 Intelligent Virtual Agent

The intelligent virtual agent assists users during navigation and retrieval of relevant information. It has the following characteristics: perception of the environment, ability to interact, user/content knowledge, certain degree of reasoning and autonomy and graphic representation. The agent's architecture reflects the following modules: knowledge base, perception, decision and action. The agent's knowledge base stores the information that it holds about the user and the environment. This knowledge is 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 observes 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 from user and observes the user’s actions in the environment. 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 actions (e.g., animation of graphic representation and speech synthesis).

The communication between the agent and the users can be made by three ways: in a verbal way, through a pseudo-natural language and speech synthesis[1], 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 and a complement, regarding the object of user interest. During the request for helping to locate information, for instance, the user can indicate (in textual interface) *Locate <content>*. The agent's answers are suggested by its own movement through the environment (moving towards the information requested by the user), by indications through short sentences, and by text-to-speech synthesis. In the interaction with provider, during the insertion of content, he can indicate *Insert <content>*, and the agent presents the data entry interface for the specification, identification and automatic categorization of the content model.

Moreover, a topological map of the environment is kept in the agent's knowledge base. In this map, a set of routes for key-positions of the environment is stored. In accordance with the information that the agent has about the environment and with the topological map, it defines a set of routes that must be used in the localization of determined content or used to navigate until determined environment area. Considering that the agent updates its knowledge for each modification in the

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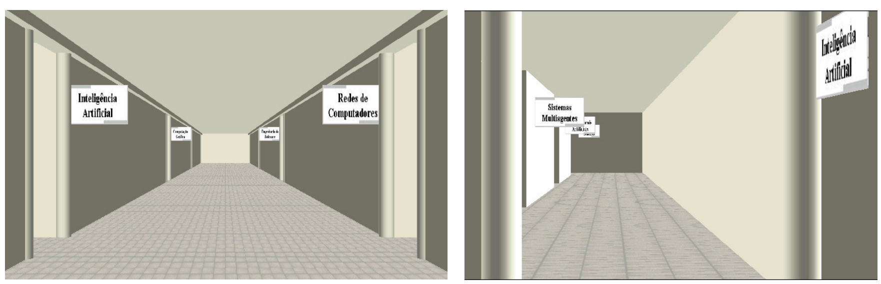
[1] JSAPI (Java Speech API)

environment, it is always able to verify the set of routes that leads to a new position of a specific content.

3 Case Study using AdapTIVE

In order to validate our proposal, a prototype of a distance learning environment [27], used to make educational content available, was developed. In the prototype, a division of the virtual environment is adopted according to the areas of the contents. In each area a set of sub-areas can be associated. The sub-areas are represented as subdivisions of the environment. In 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) – Modeling, 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 subdivisions of rooms. Fig. 2 (a) and (b) show screen-shots of the prototype that illustrate the division of the environment in rooms and sub-rooms. In screen-shots, a system version in Portuguese is presented, where the description “Inteligência Artificial” corresponds to “Artificial Intelligence”.



(a) (b)

Fig. 2. (a) Rooms of the environment; (b) Sub-rooms of the environment.

According to the user model, the reorganization of this environment is made: the rooms that correspond to the areas of major user's interest are placed, in a visualization order, before the rooms which contents are less interesting. The initial user model, based on explicit approach, is used to structure the initial organization of the environment. This involves also the use of avatars according to gender of user and the consideration of users’ preferences by colors. As the user interacts with the environment, his model is updated and changes in the environment are made. After n sessions (time window), for each area, the evidences of interest (navigation, request and access) are verified, in order to update the user model. For instance, with a user, who is interested about Artificial Intelligence (AI), is indifferent to contents related to 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 doing some navigations (N), requests (R) and accesses (A), presented in the graph of Fig. 3, the CFs can be reevaluated. According to Fig. 3, it is verified that the CN area was not navigated, requested and accessed, and on the other side, the user started to navigate, to request, and to access contents in SE area. As presented in the graph of Fig. 4, an increasing of the CFs had been identified as related to the 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.

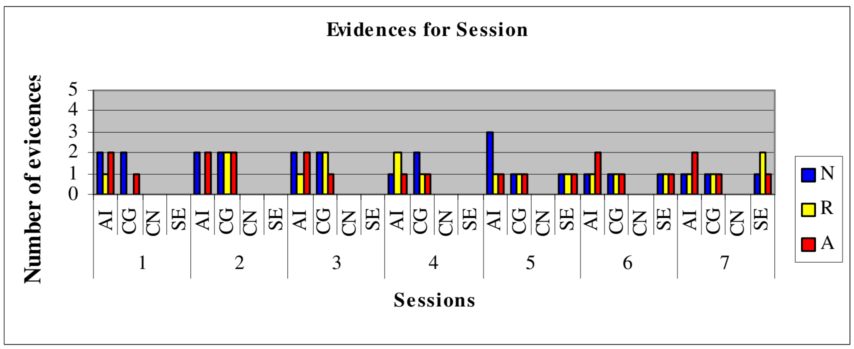


Fig. 3. Number of navigations (N), requests (R) and accesses (A) of each area, for session.

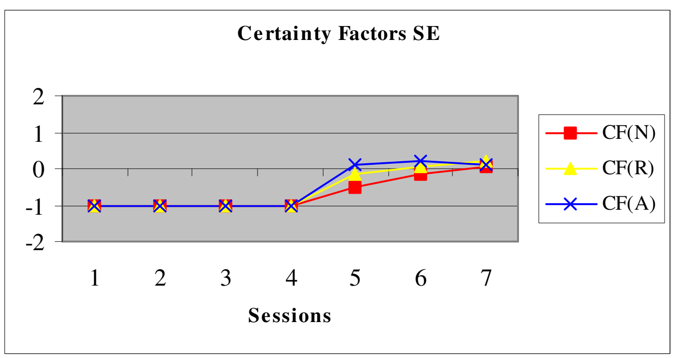
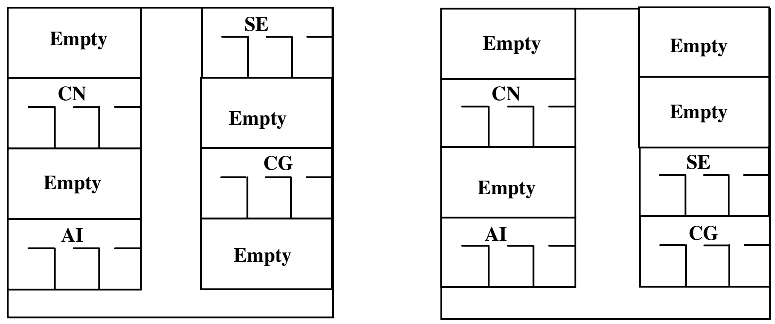


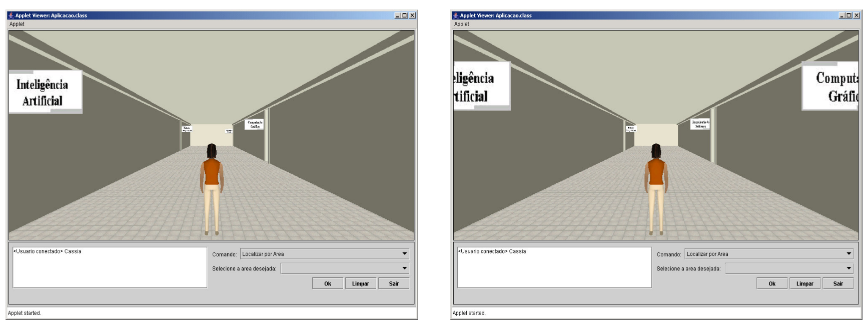
Fig. 4. Certainty factors corresponding to evidences of the SE area.

Fig. 5 (a) and (b) represent an example of the organization of the environment (2D view) before and after a modification in the user model, respectively, as showed in the example above. Fig 6 (a) and (b) show the organization corresponding to 3D environment.



(a) (b)

Fig. 5 (a) Organization of the environment according to initial user model; (b) Organization of the environment after the user model changes.

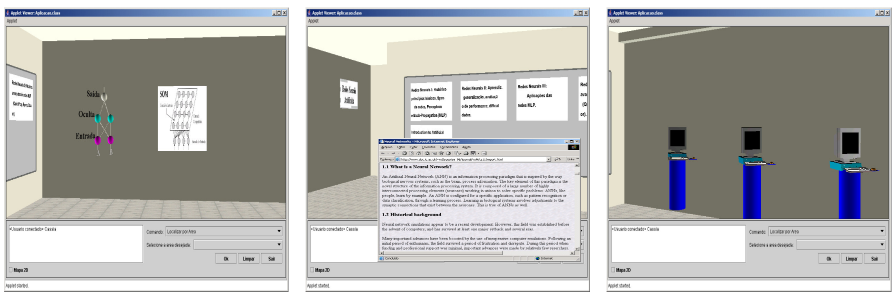


(a) (b)

Fig. 6 (a) Initial organization of the 3D environment; (b) Organization after the user model changes.

On the other side, in relation to contents in the environment, the following types are supported: *.txt, *.html, *.doc, *.pdf, *.ppt, *.jpg, *.bmp, *.wrl (VRML), *.avi, *.wav e *.au. The types that correspond to 2D and 3D images (*.bmp, *.jpg and *.wrl) and videos (*.avi) are represented directly in the 3D space. The other types (*.txt, *.html, *.doc, *.pdf and *.ppt) are represented through 3D objects and links to content details (visualized using the corresponding application/plug-in). Moreover, the sounds (*.au and *.wav) are activated when the user navigate or click on some object. The Fig. 7 (a) shows a simplified representation of a neural network (*.wrl) and a 2D image (*.jpg) of a type of neural network (Self Organizing Maps - SOM); Fig 7 (b) presents a 3D object and the visualization of corresponding content details (*.html); and Fig. 7 (c) shows the representation of computers (*.wrl) in the room of Protocols (CN).

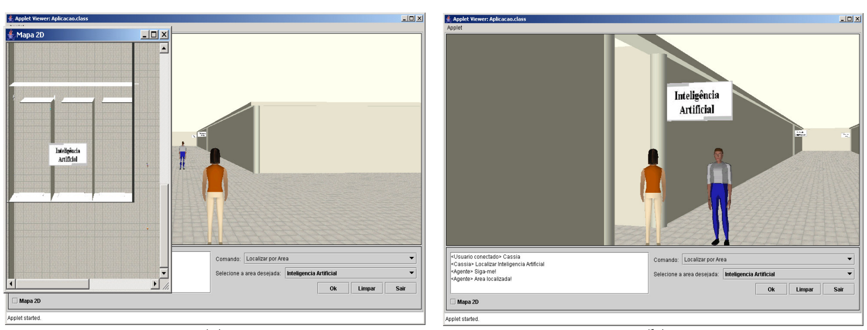
In relation to manipulation of contents in the environment, the provider model is used to indicate the area (e.g., Artificial Intelligence) that the content being inserted belongs, and the automatic categorization process indicates the corresponding sub-area (e.g., Artificial Neural Nets), or either, the sub-room where the content should be inserted. In this way, the spatial disposal of the content is made automatically by the environment generator, on the basis of its category. In the prototype, thirty examples of scientific papers, for each sub-area, had been collected from the Web, and used for learning and validation of the categorization 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. In the experiments, the binary categorization presented better results (less error and, consequently, greater recall and precision), being adopted in the prototype. In this way, for each sub-area, the rules obtained from decision tree (C4.5) were converted to rules of type IF - THEN, and associated to content manager module.



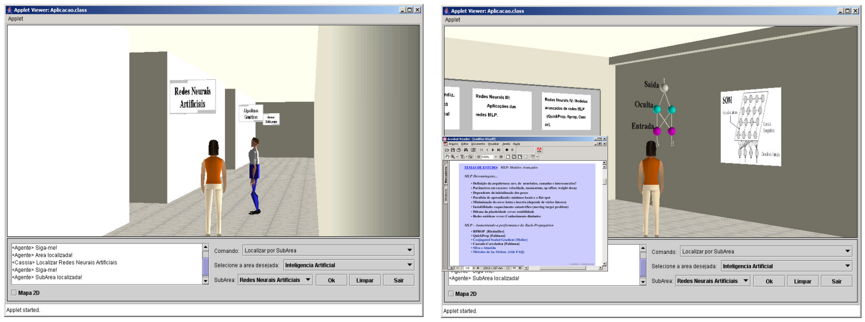
(a) (b) (c)

Fig. 7. (a) 3D and 2D contents; (b) 3D object and link to content details; (c) 3D content.

Moreover, in relation to communication process between the agent and the users, they interact by a dialog in pseudo-natural language, as commented in section 2.1. The user can select one request to the agent in a list of options, simplifying the communication. The agent's answers are showed in the corresponding text interface window and synthesized to speech. Fig. 8 (a), (b), (c) and (d) illustrate, respectively: a request of the user for the localization of determined area and the movement of the agent, together with a bidimensional environment map, used as an additional navigation resource; the localization of an area by the agent; the localization of an sub-area by the agent; the user visualization of a content and the visualization of details of it, after selection and click in a specific content description.



(a) (b)



(c) (d)

Fig 8. (a) Request of the user to the agent; (b) Localization of an area by the agent; (c) Localization of a sub-area; (d) Visualization of contents.

4 Final Remarks

This paper presented an approach that integrates intelligent agents, user models and automatic content categorization in a virtual environment. The main objective was to explore the resources of Virtual Reality, seeking to increase the interactivity degree between the users and the environment. A large number of distance learning environments make content available through 2D environments, usually working with interfaces in HTML, offering poor interaction with the user.

The spatial reorganization possibilities and the environment customization, according to the modifications (addition and removal) in the available contents and the user models were presented. Besides, an automatic content categorization process that aims to help the specialist of the domain (provider) in the information organization in this environment was also shown. An intelligent agent that knows the environment and the user and acts assisting him in the navigation and location of information in this environment was described.

A standout of this work is that it deals with the acquisition of users' characteristics in a three-dimensional environment. Most of the works related to user model acquisition and environment adaptation are accomplished using bidimensional interfaces. Moreover, a great portion of these efforts in the construction of Intelligent Virtual Environments don't provide the combination of user models, assisted navigation and retrieval of information, and, mainly, don't have the capability to reorganize the environment, and display the contents in a three-dimensional space. Usually, only a subgroup of these problems is considered. This work extends and improves these capabilities to three-dimensional environments.

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

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