

AN INTELLIGENT AGENT BASED APPROACH TO MOSAICA'S PEDAGOGICAL FRAMEWORK

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Abstract: There has been a significant amount of research in application of intelligent agent technology in virtual training and pedagogical environments. The characteristics of intelligent agents, such as flexible behaviour, autonomy and socialability make them highly suitable candidates to overcome the shortcomings of the traditional course management systems, online learning and Web resources available to learners. In this paper we propose an agent based approach to manage virtual expeditions and learning activities in Semantically Enhanced, Multifaceted, Collaborative Access to Cultural Heritage (MOSAICA) project. We believe that Belief, Desire, Intention (BDI) model of intelligent agent better serve the pedagogical requirements identified in MOSAICA project. The cognitive characteristics of MOSAICA pedagogical framework are easy to map to mental model of BDI intelligent agents.

1 INTRODUCTION

MOSAICA (MOSAICA) is an EU-IST funded collaborative project being carried out by a consortium consisting of seven EU countries and Israel. MOSAICA is envisioned as an advanced web portal, featuring multifaceted interfaces for knowledge based exploration and online utilities empowering users to collaboratively author and manage cultural resources in a globally distributed environment.

The purpose of MOSAICA is to design a toolbox for intelligent presentation, knowledge-based discovery and interactive and creative educational experience covering a broad variety of cultural heritage resources. The initial focus of MOSAICA is Jewish cultural heritage but the project is potentially applicable to other cultural heritages.

MOSAICA's proposed innovations and technical challenges include Semantic Web technologies, distributed content management, Geographical Information Systems (GIS), and pedagogical framework.

In this paper our focus will be on the management of technical issues related to MOSAICA's pedagogical framework. We propose an intelligent agent based approach for realisation of MOSAICA's pedagogical framework. We believe that the objectives of pedagogical framework of MOSAICA can be best achieved by application of intelligent pedagogical agents.

2 MOSAICA'S PEDAGOGICAL FRAMEWORK

MOSAICA's pedagogical framework is based on well know theory of knowledge known as constructivism. The constructivist theory applied to teaching assumes that knowledge cannot simply be transmitted from teachers to learners: learners must be engaged in constructing their own knowledge (Von Glaserfeld, 1987). The focus of constructivism is on promotion of active and inquiry-based learning (Bruner, 1990). In constructivist environments the learners are encouraged to create their own mental framework and formulate their own conceptual models to understand the learning material.

Technologies to support constructivist learning environments require the designing of new platforms and curricula. Effective integration of technology in a coherent and authentic way into the curriculum is not a trivial problem. However, judicious implementation of educational technology may offer means to support teaching and learning ^{[4],[5]}. One way of doing this is to integrate visualizations and virtual environments (Dori and Belcher, 2005).

Computerized visualizations and virtual worlds are used simplify and clarify abstract concepts. The use of textbooks presents students with two-dimensional drawings; however, they do not represent the true spatial nature of things. With the development of computer graphics technology, three-dimensional imaging has become a prominent

tool for representing complex structures and real-world phenomena. Incorporating visualization as part of the educational process has been found to foster students' understanding of three-dimensional structures, spatial ability, and meaningful learning (Barnea and Bori, 1999), (Bori et al., 2003), (Donovan and Nakhleh, 2001). In spite of the prevalent use of visualization and virtual worlds in the cooperative world, and the recognition of its educational value, the integration of virtual environments in school courses is still limited, mostly because of lack of appropriate technology.

Mental operations elicited by virtual environments differ from those occurring in traditional instructional settings that allow learners to experience physical properties of objects and events, such as shape, size, distance and time, and realize the actual implications of such properties. The virtual pedagogical environments have limited benefits of cooperation and coordination as compared to physical learning environments.

The learning experience in both worlds is essentially different. Real world learning environments offer myriad opportunities for observations and interactions. Real world learning incorporates body and mind experience, including all five senses. Learners physically walk amongst the observed objects, touch them (in most cases), listen to surrounding sounds, sense odours, and communicate with a guide or fellow learners to enhance the learning experience.

Transfer of the real world into a virtual environment is certainly not merely a one-to-one mapping, but must follow a complex logic of transformation. Learning in virtual worlds must be specifically designed for virtual environments. Our research will address problems of accessibility and complexity, aiming at developing an educational framework, and a platform for interactive inquiry and exploration. We intend to research how to do it efficiently, but through entertaining exploration.

Within this general research direction, a special track will be directed toward development of the methodology and the technology for *Virtual Expeditions*. Virtual Expeditions are a specific educational instrument based on conceptual modelling, and designed specifically for learning through exploration of virtual worlds. The Virtual Expedition methodology must devise a step-by-step procedural approach to the thematically driven conceptualisation of cultural resources aiming at long-term educational impact. Such a methodology will include:

1. Selection and design of pedagogical themes,
2. Development of educational content, including: (a) the general site in which the virtual expedition takes place, (b) the three-

dimensional images learners will encounter, (c) their attached textual and vocal description, (d) the conceptual relationships between the images and potential exploration paths,

3. Implementation of the virtual expeditions, including short assignments and/or extensive projects, as well as individual and/or collaborative learning, and
4. Documentation, including "tutorial" and "help" buttons, and the instructions for their use to various purposes and age groups.

Each virtual expedition will be triggered by a driving question, riddle or problem that needs solving. The students will be asked to make assumptions, hypothesize, or problem-solve an authentic issue that confronts the real world. One of the objectives is that students respond to problems that prompt higher-order thinking. Built into the virtual expedition process are the strategies of cognitive psychology and constructivism. The problems posed to students cannot be answered simply by collecting and retrieving information. In order to engage students in higher-order thinking, virtual expedition methodology will use scaffolding or prompting, that is, breaking tasks into meaningful "chunks" and steer students through a thinking process that is used by expert learners.

The Virtual Expedition methodology will offer two ways for implementing collaborative learning: (1) by assigning group assignments, and (2) by utilizing an online forum for informal text-based discourse. As part of the group assignments, students take on roles. Each student will focus on a certain aspects of the large and complex problem and become an expert in it. By running several Virtual Expedition groups in the same class, students will also see different solutions chosen by different teams.

Thus, Virtual Expedition is an innovative approach to learning in virtual environments. It offers a structured way to guide users through virtuality. Therefore, our methodology will be designed, developed and researched, so that it could be followed by other, less expert users to construct their own Virtual Expeditions.

In addition to the pedagogical research, technological research is also required, in order to develop a framework enabling design, recording and automatic execution of Virtual Expeditions. This effort must provide an online editing tool empowering end users with the ability to create and record their own Virtual Expeditions.

For demonstration purposes, research will develop few exemplifying Virtual Expeditions. These

demonstrators will be also used as tutorials and instructional material to guide end users in designing their own Virtual Expeditions. MOSAICA's repository will contain ready-to-use educational material designed for the educational personnel to use them in instruction and teaching, but also for students and other visitors to use them for individual studies. A mock up screen shot of a 1

MOSAICA's virtual expedition is shown in Figure 1 All navigational interfaces will be tightly interconnected enabling users to seamlessly move between them. For example, by selecting a certain item from the search results, users will be able to move to the GIS empowered map with related locations automatically marked on it, or to the MOSAICA directory displaying the relevant concepts and their semantic relations, etc.

3 INTELLIGENT AGENT

The definition of an intelligent agent is still subject of controversy. However, it is generally accepted that an agent can be viewed as "an encapsulated computer system that is situated in some environment and is capable of flexible and autonomous actions in that environment in order to meet its design objectives" (Wooldridge, 2000). Wooldridge and Jennings (Wooldridge and Jennings, 1995) argue that the term agent can be

used to denote a hardware or (more usually) software-based computer system that has following properties:

Autonomy: Agents can operate without the direct intervention of humans or other agents, and have control over their individual actions and internal state.

Social Ability: Agents are able to interact with other agents (and possibly humans) via an agent communication language.

Reactivity: Agents perceive their environment, and should respond in a timely fashion to changes that occur in it.

Pro-activeness: Agents do not simply act in response to their environment; rather they are able to exhibit goal-directed behaviour by taking the initiative.

Franklin et al. provide a useful taxonomy of the agents based on agent definitions arising from their functional characteristics and attributes (Stan and Graesser, 1996).

Multi-agent systems can be viewed as a collection of autonomous problem solving entities, capable of achieving their goals through interaction, coordination, cooperation and collective intelligence (Jennings et al., 1998).

An MAS is a system composed of a population of autonomous agents, which cooperate with each other to reach common objectives, while simultaneously each agent pursues individual objectives " (Jacques, 1999), (Wooldridge, 2000).

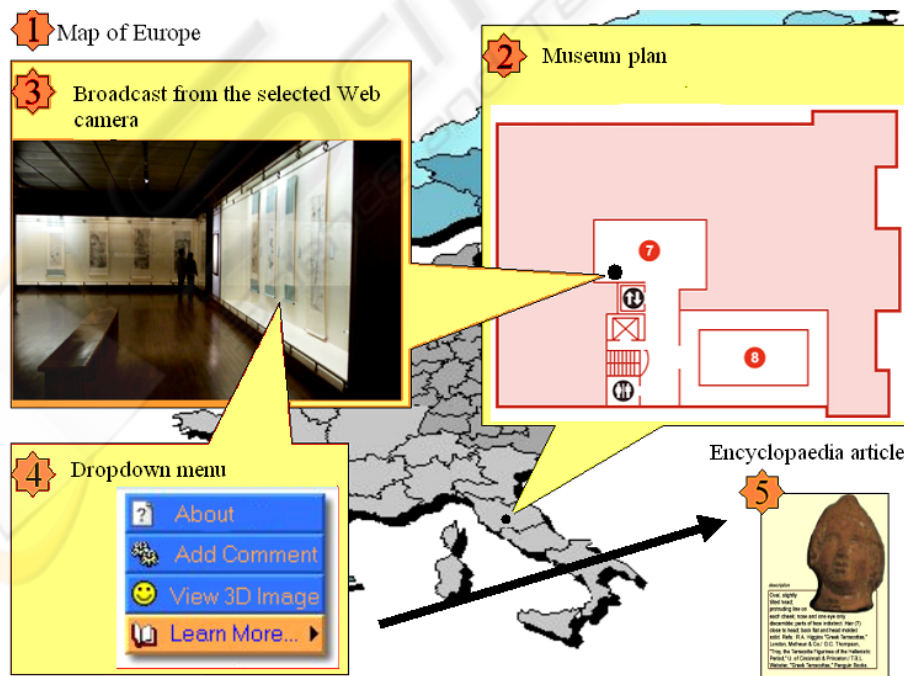


Figure 1: A Mock-up Screen Shot of MOSAICA's Virtual Expedition.

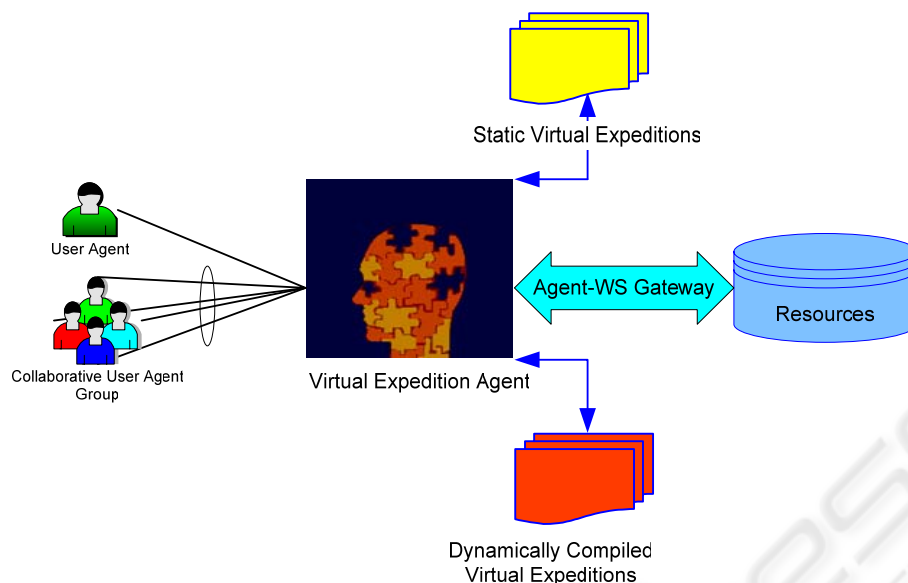


Figure 2: Agent Based Framework for MOSAICA Pedagogical Framework.

4 PROPOSED APPROACH

The original proposal of MOSAICA's pedagogical framework does not propose the use of intelligent agent technology in realisation of the framework. It leaves the technological issues involved in realisation of framework for further investigation. Our past experience of working in intelligent agent area and a growing number of research efforts related to application of pedagogical agent in online learning environment (Blanchard et al., 2006), (Conati, 2004), (Baylor, 2001) motivate us to investigate the suitability of agent technology in realisation of MOSAICA's pedagogical framework.

Intelligent agent technology provides promising approaches for modelling high level abstractions and high level reasoning. We propose the use of BDI agents in as enabling technology for MOSICA's pedagogical framework.

BDI agent model (Rao and Georgeff, 1995) is one of the most popular approaches towards the design and development of intelligent agents. The defining characteristic of this model is that the generation of agent behaviour is driven by mental attitudes such as belief desire and intentions. It aims to be a model that is a functional abstraction of high level reasoning carried out by human mind.

Our proposed approach makes use of two types of intelligent agent know as *Virtual Expedition Agent* and *User Agents* are shown in figure 2. These agents use various software components attachments in order to support their low level system functionality.

Abstract descriptions of these agents are given below.

4.1 User Agent

A *User Agent* sits between a user and *Virtual Expedition Agent (VEA)*. It is responsible for managing user interaction with VEA during a virtual expedition. It obtains user input and, formulates and sends an expedition request to VEA. This agent acts as a tutor/coach for its user and provides proactive help whenever necessary.

User agent uses two different set of rules for managing its learning and coaching functionality. These rules will be realised in the belief component of user agents. The implementation of rules set as agent beliefs enables context sensitive reasoning during presentation of an expedition to user and coaching service whenever a user needs it.

User Agent has a set plans for carrying out expeditions and coaching tasks. Each plan in agent's plan library is a recipe of actions that it executes in response to achievement of a specific goal.

Figure 2 depicts *User Agent* and collaborative user agent group. These all agents are essentially the same, but they operate in different mode.

- a) A single user mode, where a *User Agent* is serving a single user during a virtual expedition without any regard to other agents interacting with VEA. In this mode user agent uses the request-response interaction protocol to manage interaction with VEA.

Collaborative mode, where user agents interact with VEA and with each other for the purpose of collaborative learning. Each *User Agent* in a group of users agents involved in collaborative learning will focus on certain aspects of a complex problem. The group needs to be aware of contribution of each member in order to progress toward overall solution. The agents in this mode use teamwork interaction protocol for managing interaction among group members in addition to request-response interaction protocol.

4.2 Virtual Expedition Agent

Virtual Expedition Agent is at the heart of our proposed approach. It manages interactions with user agents and Web resources. MOSAICA proposes the use of Service Oriented Architecture (E. Ort) for the integration of different systems components. An Agent-WS gateway is proposed to manage seamless interaction between intelligent agents and Web Services (WS). This gateway will provide a translation service that will convert message in agent communication language (FIPA, 2000) to Web Services Description Language (WSDL) (Christensen et al., 2001) and vice versa.

VEA respond to *User Agent's* requests using an expedition from its libraries of static or dynamic expeditions or preparing a new virtual expedition if not already present in expedition library.

VEA expedition libraries contain two types of virtual expeditions known as static and dynamic expedition.

- a) Static Expeditions are few exemplifying those that will be used as tutorials and instructional material to guide end users in designing their own Virtual Expeditions. These also contains ready-to-use educational material designed for the educational personnel to use in instruction and teaching, but also for students and other visitors to use them for individual studies.
- b) Dynamic Expeditions are expeditions that a VEA agent complies in response to requests received from *User Agent*. VEA compiles these expeditions by interacting with resources via an *Agent-WS* gateway. It also maintains a record of dynamic expeditions and uses them in order to serve identical request coming from different *User Agents*.

VEA uses different kind of interaction protocols in order to maintain interactions between various *User Agents* and resources. It also supports *User Agents* in their collaborative expeditions.

5 RELATED WORK

In this section we present literature review in relation to the use of intelligent agents as pedagogical agents in order to make the case for suitability of agent technology in realisation of MOSAICA's pedagogical framework.

Johnson (Johnson, 1998) purpose the definition of pedagogical agent as special purpose agent: "*Pedagogical agents are autonomous agents that support human learning, by interacting with students in the context of interactive learning environments. They extend and improve upon previous work on intelligent tutoring systems in a number of ways. They adapt their behaviour to the dynamic state of the learning environment, taking advantage of learning opportunities as they arise*".

Blanchard (Blanchard et al., 2006) propose an intelligent tutoring system in which pedagogical agents have ability to evolve. This evolution process allows producing agents whose behaviours are fitting the learner motivational and cultural needs. They have used rule based methodology for evolution process.

Conati (Conati et al., 2006) propose intelligent pedagogical agents that can provide individualised instructions integrated with the entertaining nature of the games. They describe different ways of improving learning using intelligent agents in educational games.

Baylor (Baylor, 2001) proposes the cognitive requirements for agent based learning environments and identifies four dimension of control that must be considered in designing agent based learning environments.

Rickel (Rickle, 1998) introduce a pedagogical agent STEVE for virtual reality learning environment. STEVE handles high level cognition processing and sensor motor processing as two separate but related processes.

The cognitive process interprets the state of the world and executes plans to achieve its goals. The sensory motor process deals with its interface with virtual world.

Hamburger (Hamburger and Tecui, 1998) propose architecture for pedagogical agents that can learn from human tutor and then teach to human learners. They used machine learning and knowledge acquisition approaches in their proposed architecture.

Johnson (Johnson et al.) propose the integration of pedagogical agents into virtual environment. These pedagogical agents monitor the trainees' behaviour in virtual environment and provide them instructions by interaction with them. This integration enables trainees to get guidance and coaching in virtual environment.

Although none of these approaches deal directly with the issues related to virtual expedition discussed in MOSAICA's pedagogical framework. But these approaches do make a case for the use of intelligent agent as enabling technology in pedagogical applications. We believe that these approaches provide foundational building blocks for realisation of MOSAICA's pedagogical framework.

6 CONCLUSION

In this paper we have presented MOSAICA's pedagogical framework and proposed an intelligent agent based approach for the realisation of this framework. Intelligent agents provide an intelligent virtual learning environment, where user will engage in learning individually and collaboratively with the help of their agents. Our future work will focus on design and implementation of *User Agent* and *VEA*. We have also provided discussion of related literature in order to justify the use of intelligent agent technology in realisation of MOSAICA's pedagogical framework.

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