Editorial: intelligent agents as vicarious metacognition for the learner on the WWW

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1 Introduction

The use of computers for supporting education and business training has become a definite trend in today's complex process of lifelong learning. The world of the internet instigated the birth of a variety of new types of software, which are focused on the opportunities presented by this global medium.

Lately intelligent agents have been playing quite a major role in respect of educational support and effectiveness. They appear to be a kind of synthesis of the speed and accuracy of computers combined with human decision making. The term itself is used in many application areas and with various definitions. For us it is important to define what it means in general as a notion in the research field and how it is reflected within the context of topics discussed in the current special issue. The term 'agent' refers to a software entity that knows what the user wants and then makes use of this knowledge. The more intelligence an agent has at its disposal, the greater the extent to which it can lighten the user's load and provide other benefits [1].

This special issue is a combination of two areas of major importance these days: artificial intelligence and cognitive learning tools both in the context of education and training support. There is still a way to go in the efforts to find the best definition and application of intelligent agents in the field of lifelong learning. Thus, we had a good reason to start working on this issue and to present the best possible overview of applications, methods and tools to improve lifelong learning in terms of modelling the user, domain and the instruction, providing cognitive tools and intelligent agents for supporting both learners and teachers.

The goal of this journal issue is to provide the audience of practically oriented, training officers, developers and researchers with a more conceptual underpinning of what agents may finally mean to the 'learning community' and how they could be beneficial to the learning processes. This needs a visionary and at the same time speculative approach. We focus on three different perspectives of agents in respect to lifelong learning and global education and training problems related to knowledge management, information maintenance and support. In the first part we collected articles, which give an overview of current developments within education and training, where agents are seen as a content-addressable collective memory. In the second part, there is a set of papers that use agents as a metacognitive tool and the last part presents research on agents applied in virtual environments as a support tool for training and education.

2 Agents as content-addressable collective memory

Distributed Cognition is a philosophical notion that was first introduced by Perkins [2]. It is a hybrid theory on how individuals build their knowledge on top of each other. Hutchins imagines that knowledge resides 'between' rather than 'within' persons [3,4].

Cognitive activities are generally seen as elaborations that are propagated through media, both in and around the person. Statistically it is now very likely that one person is involved in precisely the same task as another person, thus the person-plus idea becomes quite plausible. The idea is that the web becomes an externalised electronic cortex that allows people in the same topic area build upon each other's experience, intuitions and rational processes.

In this context agents can be seen as our prostheses that enable us to extend our mental scope without demanding our attention continuously. An obvious advantage of the agent metaphor is that it incorporates the long desired 'content-addressable' memory as it just goes around with the topics that the user has in mind, so that the user no longer feels constrained by the unique labels of web pages (URLs) email addresses etc. The agent will scan list servers and web-based communities. The value for the user is different along with the kinds of retrieval. In the best case scenario the agent's output takes its master to another idea. It's also quite likely that the various agents share their results and go and find additional information that may even be of more importance to the 'master' than the results which are based on an individual search. In short: agents seem to be attractive pre-programmed entities that allow the user to act on a more strategic level instead of working with strings of information and handling communication devices. Within each system, cognitive activities are viewed as computations which take place via the '...propagation of representational state across media' within a functional system, whereby the 'representational media may be inside as well as outside the individuals involved' [4, p.373). Hence, media refers to both internal (e.g. an individual's memory) and external representations (maps, charts, computer databases, scribbles etc.). The states of the representation refers to how the various resources of knowledge and information are transformed during the conduct of an activity.

Using agents, it is possible to combine CSCL paradigms with AI techniques, which contribute to higher intelligence and effective collaboration. CASSIEL (Ayala, G) is a Computer Assisted Intelligent Environment for Learning that is a good example of such a combination. It supports the awareness in universities of the real needs and developments of software industries for the latest advancements in computer science. Agents in CASSIEL are modelled in order to support the development of lifelong learning skills and the social construction of knowledge within the community, whilst maintaining an awareness of relevant IT issues and maintaining communication and cooperation among the participants. Another good example of agent support for cooperative learning is presented by Sofiane Labidi and the SHIECC project aimed at a cooperative learning system for engineering courses. It discusses an agent-based software package that integrates cooperative learning with computer, multimedia and network technologies. The main focus is on the conceptual model of the system in respect to cooperative learning strategies and cooperation between the related heterogeneous agents (humans and software) presenting different roles and characteristics. Herna Viktor introduces a new methodology that tries to combine human learners and inductive machine learners, which learn from data, into a cooperative multi-agent learning system. Here learning techniques are used to model computational cooperative learning systems for the discovery of new

knowledge. Some results are presented that prove the efficiency of this approach for knowledge acquisition. Jorge Sagula, Martin Puricelli and Gutavo Bobeff also address the problem of computer-based collaboration in education and training and look at how agents can be applied to support processes there. Another example of how emerging technologies, like XML, DOM, Corba and intelligent agents can be applied to practical distance learning applications are Persona and SoftDoc systems, presented by Junichi Suzuki and Yoshikazu Yamamoto. They provide a personalisation and collaboration service to a set of courseware in respect to the context of the content and/or presentation within the current context of software modelling. In the work of Artificial Intelligence and Knowledge Computing Lab at the University of Electro-Communications, Tokyo, presented by Ryo Takaoka and Toshio Okamoto, agents are used to provide a variety of functions for students in order to provide dynamic solutions for various situations which go beyond the typical intelligent tutoring system. They discuss issues such as agent-based guidance and pedagogical agents. George Vouros focuses on issues such as information adaptation and presentation, aiming at generic architecture for cooperative learning environments. The paper proposes intelligent learning environments that provide students with information support, where the target is to support natural communication and effective collaboration between people and systems. Here agents collaborate effectively with 'users towards completing a partial shared plan for achieving users information needs, as well as among themselves, towards completing a partial shared information presentation plan for achieving tutorial goals.'

3 Agents as metacognitive support tools

The notion of 'learning to learn' and 'knowing what you still have to learn' is often epitomised as 'meta cognition'. Metacognition enables us to be successful learners and has been associated with intelligence in some previous works (e.g., [5–8]). Metacognition refers to a higher order of thinking, which involves active control over the cognitive processes engaged in learning. It plays a major role in the learner's success in acquiring new knowledge. There are numerous theories about learning and thinking skills and the way in which we can develop these skills. Along with this there is an important distinction between cognitive processes (ie. cognition) and executive functioning (ie. metacognition), finally knowledge content is developed. This knowledge is called metacognitive kowledge often associated with John Flavell [9], according to whom, metacognition consists of both metacognitive knowledge and metacognitive experiences or regulation. Agents appear to be very suitable entities for realising metacognition as a support for computer assisted educational and training environments.

In her paper Judith Masthoff presents the APPEAL system, a domain-independent artificial teacher, where a group of agents, each with their own competence, interact with each other and with the students in order to achieve emergent adaptive functionality of the system. Other types of pedagogical agents are presented in the work of Ana Paiva and Isabel Machado on the web-based training environment TEMAI. The synthetic pedagogical agent Vincent is applied in a distance training course for workers in the footwear industry. Vincent helps the trainees throughout the learning process and motivates them by generating encouraging messages. Vincent combines a set of sensors and actors that establish message-based communication with the micro-learning

environments while gathering information about trainee performance. The example of Vincent allows us to view the application of emotional attitudes for an agent entity.

4 Agents as part of our virtual learning world

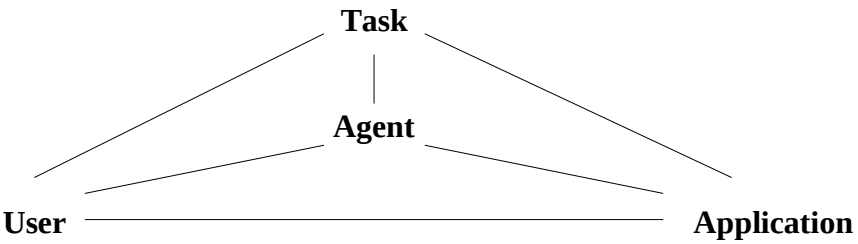
The use of Intelligent Virtual Environments has grown considerably over the past few years. The application of intelligent agents in this area can offer significant effectiveness for 3D learning and training environments. They have the requisite abilities to support a range of complex learning and system tasks, they offer a strong visual presence and contribute greatly to user friendliness and flexibility in virtual educational systems. Combined with the strong points of Virtual Worlds for learning, teaching and training, they have become an essential part of today's electronic-based education and training. In this issue the work of Timothy Norman and Nick Jennings presents the results and experiences of the Trilogy project, which worked on the development of a virtual research laboratory using intelligent agents. The laboratory is designed to support the training of research students in telecommunications traffic engineering. An intelligent tutorial agent has been designed by Domitile Lourdeaux, Jean-Marie Burkhardt, Franck Bernard and Philippe Fuchs, in order to support the learning process with the help of Virtual Reality. The agent here is based on a cognitive taxonomy of the trainee's behaviour. An application of this intelligent agent is being implemented in a VR simulation-based training system for SNCF train drivers. Another paper examines ways in which internet-based tools can enhance and provide efficient and cost-effective training both in academia and in industry. Agents are seen here as an enhancement to packages such as Mathlab and Mathematica and as essential to the process of distance learning in respect to the efficient control and management of access to facilities and software; effective user navigation to the requested relevant information; information protocols; effective distance tutoring techniques; and on-line decision support systems. In the context of information management and maintenance, there is another example in a different area of application-financial news. Marko Turpeinen uses intelligent agents for the process of personalisation and augmentation of financial news, where different agents are assigned to the tasks of profiling, mediation and augmentation. All of them take an active part in the process of profiling individual users, mediating between the various types of data resources, combining them into an XML based format and augmenting the data as necessary into an appropriate format for the reader. Agent technology appears to be a promising approach for addressing the challenges of modern day educational environments, which are influenced enormously by advanced information and internet technologies. Agent technology has been recognised as being useful in quite a lot of educational and training computer-based activities. The existing world of education is currently changing rapidly in response to all the new technologies and methods coming up on the market. This change is also taking place in technological as well as in instructional methods that are used in traditional and on-line education. Intelligent agents appear to offer rather important advantages for the scientific and educational computing worlds. They have a major influence in different fields of educational systems. They provide new educational paradigms, support theories and are rather helpful entities for both students and teachers alike in their computer-aided learning-teaching process. Their application in the educational field is mostly as personal assistants, user guides, alternative help systems, dynamic distributed system architectures, human-system mediators, etc. The former

changes imply that on the one hand increasingly complex and dynamic educational infrastructures need to be managed more efficiently and, on the other hand, new types of educational services and mechanisms need to be developed and provided. It is in particular such services that need to satisfy a diverse range of requirements, such as personalisation, adaptation, support for user mobility, support for users while coping with new types of technologies, effectiveness, information support, etc. Agents appear to support these requirements in a more efficient way in comparison to other existing technologies. Besides the ability to act autonomously and to cooperate between themselves, agents possess the capabilities to deal with issues such as security, both on-line and off-line service providing, etc. When a new paradigm is introduced the most important issues are definitions with major characteristics, taxonomies, operationalising concepts, functionality and application. Intelligent agents have characterised a large range of definitions. An extensive overview of them is not the express purpose of this article. A good overview can be found in Franklin and Graesser [10] and Jennings and Wooldridge [11]. In particular, there is no real agreement on what an agent is. Agents' abilities vary significantly, depending on their roles, capabilities and environments. In order to describe these abilities different notions of agents have been introduced. Intelligent agents are introduced by most of the researchers, Wooldridge and Jennings [12] and Jonker [13] with four major concepts defining their behaviour: autonomy, responsiveness or reactiveness, pro-activeness and social ability. There is also a strong notion on the characteristics of agents, which refers to adaptiveness, pro-activity and intentionality, [14-16]. There are also various taxonomies created for agents. According to Nwana [17] there are seven categories of agents – collaborative, interface, mobile, information, reactive, hybrid and smart agents. Franklin and Graesser [10] identify a taxonomy, which is enhanced with categories by Nwana and restructured. Some new categories are included, such as 'life-like' agents. In this context, intelligent agents are associated with a variety of functions, such as personal assistants, information managers, information seekers, planning agents, coordination agents or collaborative schedules, user representatives, etc.

5 Architectural view on agent technology

From an architectural point of view agents act as mediators between users performing specific tasks and a specific software application. They are often decomposed into functional modules, which refer to perception, modelling, planning, coordination and task or plan execution. The point is that the agents have the ability to execute and coordinate sub-tasks independently and autonomously, which leads to the completion of the major user task. Recent trends have made it clear that software complexity will continue to increase dramatically in the coming decades. The dynamic and distributed nature of both data and applications means that software needs to not only respond to the request for information but it also needs to anticipate, adapt and actively seek ways to support users. In this context users expect dedicated assistance from the applications they are using. In response to these requirements, software agents play an important role in human-computer interaction and in the coordination of the internal processes of the system.

Figure 1 Functional embedding of intelligent agents



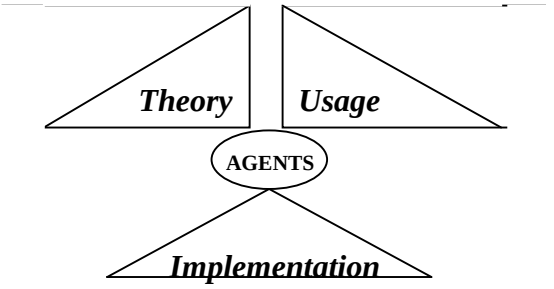
From a functional point of view we see agents in the context of the different roles they could be applied to. Conceptual structures play an important role in the functional operationalisation of the agent. They could be applied to knowledge representation and its manipulation mechanisms, to navigation and to problem definition. In this context ontology plays an important role. The term ontology has been recently adopted by the artificial intelligence community to refer to a set of concepts or terms that can be used to describe some area of knowledge or build a representation of it. Ontologies bring about quite a fundamental change in the way systems are constructed. Also in combination with an agent they create a really future-oriented approach in coping with the complexity of the new information age. They are referred to as vocabularies, content theories, world descriptions, shared and reusable knowledge representations and task definitions. In this respect agent-based intelligent systems can provide a completely new understanding of the computer and its functionality.

6 A structural view of agent technology

The structural point of view concerns the intersection and combination of theories and the implementation and usage of intelligent agents in the specific application area of education.

The introduction of agent technologies sketches the history of this new paradigm. Different points of reference are used in order to present a clear and structured picture of the main issues involved, the concepts and considerations for the design and the realisation of agent-based educational software.

Figure 2 Intelligent agents in the context of theory, implementation and usage



7 Conclusions

As we have already entered the knowledge society it is quite clear that in any business or educational organisation one of the most vital tasks is to effectively manage the knowledge and information within it. The challenges are to identify the important parts and roles within this process, to describe the user's needs and to select the proper tools to realise this. We believe that in this issue we manage to cover the major aspects of learning support for computer-based education and training in respect to information and knowledge.

The general conclusion of all the papers presented seems to be that the characteristics and abilities of intelligent agents are quite essential to effective computer assisted learning. However this is just a part of the total solution, which is provided by integrated approaches with traditional and innovative techniques. We see how agents in combination with traditional techniques and methods for learning and teaching and innovative techniques for information visualisation and conceptual modelling, form a definite trend nowadays in lifelong education and training. To make a final conclusion, we have to say that all the presented prototyping and evaluation has enabled us to identify in detail the issue of conceptual support in the process of learning and teaching and to see the importance of development and support for meta-cognitive skills and awareness.

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