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MAPIT: a pedagogical-relational ITS

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Abstract

The majority of Intelligent Tutoring System architectures are focused on supporting learners through content retrieval or in one or more given subject matters; examples of this can be found in Baghera [1], MyClass, Andes [2], Gramy, Advanced Geometry Tutor [7]. The implementation of such architectures are time-consuming and are generally not interoperable with other domains [3].

The presented research describes the experimentation of a Open Source, LMS enhanced with elements of AI aiming at supporting online teachers’ and tutors’ work by using a KB specific to relational and pedagogical aspects, not connected to a specific subject matter. Such implementation needs to be provided of an authoring tool easily and readily usable by tutors and teachers of different subjects and with medium level IT training.

Starting point of our investigation has been a preliminary analysis of machine-mediated, human-human interactions (MM-HHI) and communications by using the Teachers’ thinking approach [4] [5] [6]. We considered messages exchanged between teachers/tutors and online students in three post-graduate, online courses running at the University of Macerata during 2008 – 2010 by the Faculty of Education. The study showed that about 30% of messages concerned structured information that could be straightforwardly retrieved by an artificial agent; almost all remaining messages were instead deeply bound to student’s learning path or required a significant input by the teacher/tutor, while the residual part of messages could – to some extents – be delegated to an intelligent agent having access to students’ tracking data in order to display visual information to users or trigger alarms to tutors.

The investigation carried out prompted us for the deployment of an Open Source chat-bot system that would retrieve information already coded into the courses or originated by students through the analysis of their activity logs; the chat-bot agent uses this structured information in order to answer students’ most common questions hence relieving teachers and tutors from doing this repetitive task. The system is being implemented on a OLAT ver. 6.3 LMS loosely coupled to a JADE-based Multi Agent System in charge of processing user tracking data and running the ALICE chat-bot integrated with the platform messaging system.

*Keywords:* Teachers’ thinking, Intelligent Tutoring System, Multi Agent System, Learning Management System, Tracking data, Chat-Bot

1. Problem Statement: subject matter specific ITS

Most important applications for intelligent agents deployed for learning purposes are mainly two, with in both cases a strong binding to the domain of knowledge, its ontological representation and related information; these are:

* The retrieval of pertinent study resources personalized to learner’s profile, needs and progress
* The preparation of cognitivist learning paths aimed at the acquisition of subject related knowledge and skills.

In the former case agents need to perform an analysis of learner’s needs and subsequently find relevant resources; resources can be any kind of text and document that can be retrieved from the net – through semantic services for instance – or learning object and in-depth extra material that are suggested to the learner basing on his objectives, preferences, test scores or difficulties met along the path. A few industry standards, among which IMS LD[[2]](#footnote-2), have been designed to meet only some of these requirements.

In the latter case we find subject matter focused applications where extensive, discipline specific knowledge bases are required in order to guide learners through step-by-step, hint-based paths; some examples of these type of applications are:

* BAGHERA: a web-based, multi agent VLE capable of supporting teachers and students in designing and solving geometry problems [1]
* MYCLASS: a management training support tool developed by IPS[[3]](#footnote-3)
* ANDES: a physics tutoring system deployed in many US colleges and high schools [2]
* GRAMY: a geometry theorem prover capable of construction [7]
* ADVANCED GEOMETRY TUTOR: an intelligent tutor that teaches proof-writing with construction [8]

Other applications in this category are POINT&QUERY, AUTOTUTOR and iSTART by Arthur Graesser [9]:

“*Point&Query, AutoTutor and iSTART were designed to facilitate explanation-centered learning through strategies of inquiry and metacognition while students learn science and technology content. Point&Query augments hypertext, hypermedia, and other learning environments with question–answer facilities that are under the learner control. AutoTutor and iSTART use animated conversational agents to scaffold strategies of inquiry, metacognition, and explanation construction. AutoTutor coaches students in generating answers to questions that require explanations (e.g., why, what-if, how) by holding a mixed-initiative dialogue in natural language. iSTART models and coaches students in constructing self-explanations and in applying other metacomprehension strategies while reading text. These systems have shown promising results in tests of learning gains and learning strategies*” [9].

Applications of the former category, while undoubtedly support online teachers and tutors in the retrieval of relevant study material, seem to restrict the learning process to a resource supply approach. Applications of the latter category present also interesting features and positive impact has been verified by several studies [10]. Although we find their main limitations being:

1. Strong binding to a restrict subject field making them hardly reusable for different disciplines
2. The construction of needed knowledge base, ontology, or dialog tree is highly time consuming and the required effort is judged sustainable only with a considerable number of learners over several years
3. Learning paths realized through these systems are mostly inflexible due to the implicit cognitivist approach utilized; online teachers and tutors have little freedom to adapt contents to individual goals and objectives, for instance, that may change underway.
4. Purpose of Study: an open ITS

Further researchers as Koper, [11] endorse a mixed approach, combining the utilization of software agents with the semantic web, in order to identify new learning design models rather than focusing on specific discipline centered learning paths; some key elements of this can be found in the following excerpt:

“*The use of the semantic web in education is explored. Two application areas for use are discussed: a) software agents that support teachers in performing their tasks in flexible online educational settings, and b) software agents that interpret the structure of distributed, self-organized, self-directed learning networks for lifelong learning. The resulting information is used by learners to help persons them perform their tasks in this context more effectively and efficiently. Both of these tasks require a semantic representation of educational entities, specifically the structure of the teaching-learning process, in order to allow for automatic processing.*

*Self-organized learning networks provide a base for the establishment of a form of education that goes beyond course and curriculum centric models, and envisions a learner-centered and learner controlled model of lifelong learning. In such learning contexts learners have the same possibilities to act that teachers and other staff members have in regular, less learner-centered educational approaches In addition these networks are designed to operate without increasing the workload for learners or staff members. Mechanisms responsible for this efficiency are principles of self-organization and software agents. Both of which are based on semantic web principles that provide support and regulative feedback for both learners and teachers*” [11].

The concept of self-organized learning networks – as already introduced by Varela et al. [12] – plays a central role within this idea. The organization of the learning environment/path is not given as result of a deterministic process but, as opposed to cognitivist models, evolves and restructure itself basing on the interactions taking place between its users; in this view the role of online teachers and tutors is not secondary.

This is the direction followed by our joint research team CELFI-CIRDIFOR at the University of Macerata where we focus on the following objectives

* To support teachers and tutors in order to make online tuition sustainable and effective
* To develop and experiment learning paths leveraging different approaches (e.g: cognitivist, socio-constructivist) with significant online interaction
* To design learning environments able to support ever changing learning paths and processes that teachers and tutors can adapt to arising needs.

The theoretical background is taken from Teachers’ thinking (Shulman) [4], from the “New Didactic Research” (Damiano) [5] and from complex, situated design models - as already introduced by Gero [13], Koper [11], Cantoni et al. [14], Rossi and Toppano[15].

Starting from this the first step in our investigation has been to analyze messages exchanged between teachers/tutors and online students in three post-graduate, online courses run during 2008-2010 by the Faculty of Education; the study allowed to assess functions and quality of interactions carried out by online tutors.

Since teacher’s and tutor’s roles vary far and wide according to adopted pedagogical strategy, the described research considered a specific context with teachers coming from different backgrounds and educational philosophies in order to widen the applicability of this study.

1. Methods

Courses chosen for the analysis of interactions have been designated basing on:

* Experienced, highly qualified and competent online tutors
* Significant number of students per course
* High number of online interactions made through web 2.0 tools (forum, chat, wiki).

All courses considered for this study adopted a approach where both peer interactions and reflection activities are regarded important.

Further to that, all courses matched the features described: learning path vary each year according to cohort profile and context, reflective processes are activated, teacher and tutor involvement is significant in giving highly situated, personalized input.

Courses concerned by this study involved 208 students (teachers, trainee teachers) from different subjects and with different geographical-cultural backgrounds; students have been divided into groups of about 25 members. The designed learning path required students to carry out several activities at the same time and participation to discussion forums served different purposes:

* ask for information to teachers and tutors
* debate on given subjects
* organize collaborative activities within study groups
* discuss about assessment and self-evaluation with tutors.

Different forums required diverse types of participation and produced different relational and argument styles. The main difference between the above-listed types of forums has been observed in relation to thread length and structure of discussion: in the first type of forums inputs displayed single question-answer construction, whereas in other forum types has been observed a more complex structure of replies.

In this phase of the study the analysis focused on the forum’s first type. All messages show characteristics better suited for the focus of our research; as anticipated by our experienced tutors, a significant share of forum’s first type messages requested information already coded within the course activities and study material.

The analysis carried on with reading and classification of single messages; tags associated to messages served the purpose of cataloging posts under three main aspects:

1. Category of message: question, answer, statement, acknowledgement/appreciation
2. Relevant keywords
3. Required information already coded within course/activities/study material.

The same analysis has been performed by two researchers who have read the same messages and than compared and negotiated meanings depending on Miles and Huberman [16] model.

1. Findings and results

Data collected from the “Help forum” of cohort A in a course running for a nine-week period presented 145 messages divided into 52 threads, 18 unique participants with an average of eight messages per user; students posted a minimum of one message to a maximum of 11, with an average of 4.5 and a standard deviation of 2.6, while the assigned tutor posted 62 messages. It has been estimated that monitoring and moderation required between 20 and 30 minutes of tutor’s time per day only for this single forum.

As with regards to the third classification item listed above, collected data concerned all support and info forums available for each of the five student groups analyzing, collectively, 1432 messages; results of the analysis is shown in table 1.

Table 1 – Analysis of messages in support and info forums

|  |  |  |
| --- | --- | --- |
| Category | % of total | % of total – tutor’s messages |
| Information already coded within course/activities/study material | 27% | 42% |
| Acknowledgement/appreciation | 10% | 15% |
| Assessment request | 8% | 13% |
| Other | 19% | 30% |
| Tutor’s messages | 36% |  |

Data shown in Table 1 displays five message categories, follows a detailed description for the first three:

* Information already coded within course/activities/study material: messages catalogued in this category include questions concerning deadlines, test modality, features of assignments and study resources
* Acknowledgement/appreciation: messages in this category usually end a thread by thanking tutors for given answers. Although this kind of messages do not usually require a reply, it could be useful to have them marked as Non-urgent by an automated cataloguing system so that tutors, for instance, won’t have to read each one of these during pressuring times
* Assessment request: these messages are usually sent from students to solicit tests scores and qualitative-quantitative assessment motivation. These information can be easily examined from a dedicated page within the LMS; replies to this kind of messages could be processed by a software agent having access to platform and students’ tracking data.

Overall collected data indicates that, for this types of help forum, only 30% of messages required an in-depth analysis by tutors and therefore up to 70% of learning support activities and moderation work could be carried out or partially facilitated, by software agents.

1. Conclusions and further work

If we connect the results of this analysis with the analysis of another types, you may notice that the role of online teachers and tutors is certainly not restricted to provision of study material and resources; in contrast, their chief functions are:

* Guidance, motivational and methodological advice throughout the learning path
* Time and process management
* Design and planning of resources and learning actions in relation to subject and context
* Facilitate relational issues within the cohort as well as with individuals
* Observation and assessment of learning process and outcomes.

With respects to the first two key functions it is necessary to clarify that information about the whole learning path/process need to be continuously reinforced throughout the whole course on the basis of questions or requests for clarifications that arise from students. This emerges very clearly from the analysis carried out where many answers consisted in pointing out students to resources and information already available in the LMS.

Most importantly, the study results show that 42% of all questions posted in help forums, concerned information already coded within the course activities (e.g: deadlines, progress) and that could be hence delegated to a software agent having access to course and students tracking data. Furthermore, through a semantic analysis of non-help forums, we hypothesize a message classification system able of highlighting the ones requiring a high-level, situated answer, from the ones that do not require an answer at all (e.g. messages of acknowledgement/appreciation).

This investigation work needs to be furthered along two main tracks:

* Extend the analysis to other types of forum, namely those specific to subject discussion, in order to verify whether it is possible to suggest pre-configured answers to teachers and tutors or if an automated message could satisfy the student’s enquiry. Possibilities in this direction include the extensive processing of tracking data to obtain relational indicators giving teachers and tutors an outlook over class and individual progress; this would activate self-regulative learning processes [17] and will help the detection of problematic situations. A second option is to exploit semantic services and software agents to match message content with subject-specific knowledge bases
* Experimentation of a chat-bot agent as information inquire and retrieval interface; the chat agent would interact with users through the LMS internal messaging system enabling a synchronous, on-demand, first-level help desk service.

Both tracks require an extensive exploitation of users’ tracking data (e.g.: single actions/clicks performed within the LMS) and a multi-agent system (MAS) based architecture in order to carry out scheduled, as well as on demand, complex calculations. For this reason we include a brief description of the MAS architecture we have developed as grounding platform to advance with this research.

* 1. ITS system architecture

The design and implementation of an independent tracking and monitoring system focuses on an modular and easily extendible architecture (see Fig. 1). The system is hence made up by four main components:

* A logger adapter based on messaging techniques
* A MAS-based infrastructure
* A client XMPP
* Different web services as interfaces.

Due to the heterogeneity of the LMS systems present on the market, we have studied an easy and fast solution to link information among systems. That heterogeneity is addressed by providing each LMS with a simple adapter that publishes data in a comprehensible format using standard technologies as Message Broker and XML. About the Message Broker we introduced in our architecture ActiveMQ, a software service for message routing able to exchange messages decoupling sender (LMS) and receiver system (tracking and monitoring system). This solution has many advantages, first of all the simplicity. Actually it is needed a few set on instructions to develop a simple adapter for each different LMS system. Second, the adapter is just an extension of the logger or audit manager present on every LMS platform so the introduction of a new component does not effect on existing systems.



**Fig. 1.** The multi-agent architecture from a computational point of view. On the bottom, the agent platform governing the entire process. In the middle, the agents that manage the communication with the LMS. On the top, the agents implementing the rules governing the intelligent tutoring system.

Through this logger adapter we can catch and send every single action of users in a standard format. In this way, the Messaging technology is highly reliable and scalable for our environments, making possible the exchange of an high volume of messages per second. Messages contain different data about platform, about the user and his roles, and about the action made by the user. We already developed and deployed our first adapter for the OLAT platform. The logger adapter makes possible to track every single user action on the course and specific information for particular course elements as forum and chat. When the Message Broker receives a new message, it routes the information to our MAS. That agent architecture has been developed using Jade (Java Agent Development framework) and is composed by different agents, among which the most important are the following:

* Broker Agents, residing in the middle layer, have the responsibility to route new messages to special purpose agents (User Agents) for real-time analysis and to store information for a scheduled post analysis
* User Agents, on the top layer, are created and disposed automatically by the system when new students enter into LMS platforms.

These agents respond in a real-time environment directly to students using XMPP protocol with information that may be taken from an inference engine. The User Agent and student interaction supports bidirectional exchange of information so when the software agents write new messages based on student activity, for example when a student open a forum the agents inform him about the possibility and importance of collaborating; the students can then interact with the system using the LMS internal chat system.

At the moment we have implemented different agents behaviors based on AIML standard (Artificial Intelligence Markup Language) with generic knowledge repository. Our plans are to build a special web interface only for e-tutors to support the growing of knowledge repository; in this way teachers and tutors will have the possibility to add course-specific information to the knowledge repository.

Scheduled Agents, support intensive computational analysis. Such effort is related to user profiling and collective profiling (for instance the behavior of a community of student in a forum). More precisely, they build and update user profiles, course profiles and special course elements profiles. Considering single user sessions, the agents just elaborate user navigation path and make possible to compare data related to different dates.

Elaborated profiles can be analyzed by tutors and teachers on the LMS platform by special interfaces based on Web 2.0 standards as all retrieved data from our tracking and monitoring platform is available by open web services. We have deployed different web services to make possible further interaction between external analysis tools and to support service orchestration techniques.

The system described has been implemented and the LMS is currently used by the University of Macerata in graduate and post-graduate courses attended by over 2000 students. The next research step will analyze if the integrated chat-bot and all tracking tools will simplify the activities of tutors and teachers and how modify their activities.

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2. The full specification of IMS LD can be found at *http://www.imsglobal.org/learningdesign/index.html* [↑](#footnote-ref-2)
3. Source: *http://www.ipslearning.com/corporate-learning-solutions/myclass-learning-support-solution.html* [↑](#footnote-ref-3)