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ACHIEVEMENTS OF LEARNING DESIGN IN MULTI-AGENT MULTI-LANGUAGE INTELLIGENT SYSTEMS – THE I-TUTOR APPROACH

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Introduction

This paper is discussing the scientific background of a multi-agent educational robot design from the designer's point of view. From the early years of the systematic use of Instructional design, educational scientists wanted to use the results of artificial intelligence to support authors, developers, researchers, in their pedagogical work to create "automatic" course designing machines or make the built in process more and more responsive and adaptive to the tuition circumstances, therefore design a more intelligent training material (Bramucci & Zarka, 2012). The tracks of this huge work shows that the approach of the robotisation of instructional design approach is more slow that was initially expected. The last thirty years' developments in this discipline therefore are still in an emerging phase. The problem of not knowing how we learn, and the limitation to theoretically describe any learning content, leads us to particular solutions for particular problems. General solutions need radical changes in the approach.

The aim of the I-Tutor project (http://www.intelligent-tutor.eu) is to develop this multi-agent based intelligent system to be applied in online education and that does not rely on a deterministic approach. Students and teachers could, thus, take advantage of the ITS as a boundary object to regulate teaching and learning process during their actions in a way that could be personalized and foster reflective processes. In this paper we show examples of some mayor research steps towards the solution of intelligent instructional design, and conclude to a new approach of learning design that was used in the I-Tutor project aiming at testing a new educational robot containing learning design elements as well.

Instructional design and artificial intelligence

Definitions

Artificial Intelligence

Artificial intelligence (AI) is the intelligence of machines or software, and is also a branch of computer science that studies and develops intelligent machines and software. Major AI researchers and textbooks define the field as "the study and design of intelligent agents" (Poole, Mackworth & Goebel, 1998).

Instructional Design

In narrower sense ID is the practice of creating "instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and appealing" (Merrill, Drake, Lacy & Pratt, 1996). Or "Instructional Design is the systemic and systematic process of applying strategies and techniques derived from behavioural, cognitive, and constructivist theories to the solution of instructional problem" (Mizogouchi & Bordeau, 2000).

Instructional Systems Design

The broader sense of Instructional Design is also called Instructional Systems Design (ISD) and it deals with the construction of the whole model of the instructional process. A model is a mental representation of something else, an object or a process required, because of dissatisfaction for status of real things. Therefore an instructional model describes an instructional experience required, imagined and patterned in the design. Consequently also an instructional pattern can be defined a cognitive artifact, because it is a real object designed and constructed for a problem solving. One classical model of ISD is the ADDIE model (Branson et al., 1975).

Categories of ID

There are many possible categorizations of ID. To our scope of examining the roles of AI in ID we have to distinguish three settings:

- student-only;
- teacher-led;
- community-based settings.

Instructional design in its "pure form" can be observed in the student-only settings. Here the student is instructed by the machine. We initially do not observe the possibility of teacher intervention or the existence of other learners, who obviously affect the learning process. This approach is common in the literature, as Koschmann (1996) describes. Since one-on-one tutoring is commonly considered the gold standard against which other methods of instruction are measured (Bloom, 1984), the paradigm is founded on the proposition that

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education could be globally improved by providing every student with a personal (albeit machine-based) tutor (Lepper, Woolverton, Mumme & Gurtner, 1993). I-tutor approach going beyond this student-only setting.

Roles in ID

In the light of AI we have to define roles in computer enhanced (student-only) tuition, to narrow further the topic:

- Designer: The pedagogical or andragogical expert (or group) who is preparing the instructional program before the learning takes place. This role is typically the role of a teacher, but in many cases in larger Universities and Institutions that deal with distance education and on-line learning, this is already an exclusive role, already a profession.
- Tutor: There are many common definitions of tutor. We call tutor the andragogical process expert, who has a "working knowledge of the subject for discussion but they will also have a concrete knowledge of facilitation and how to direct the student to assess their knowledge gaps and seek out answers on their own" (Davis et al., 1992). This knowledge in self-directed learning (student-only setting) is in most cases dealing exclusively with facilitating the self-learning path, by technically helping to work with the machine led instructional material and to help in detail by pacing the material. Tutor's important role is to develop meta-cognitive skills, like discovering and understanding the consequences of the learner's learning style.
- Learner: Learner is in AI terminology the human who is following the programmed instruction.
- Machine: Program which is giving the instruction and processing learner input. This program can be itself the robot, or agent, but the machine can be designed by the author(s) with help of AI (authoring agent).

I-tutor is adapting this approach by defining the role of instructional designer, tutor and student.

Pedagogical agents

The problem of developing machines that intelligently teach (Intelligent Instructional Systems) has a long history. The research work started with pedagogical agents. The development of pedagogical agents appeared to be so complex that further research focussed on authoring agents. Authoring agents are not directly instructing learners but intelligently help authors do make effective instruction. The need for intelligent instructional systems emerged.

> *"Pedagogical agents are autonomous agents that occupy computer learning environments and facilitate learning by interacting with students or other agents. Although intelligent tutoring systems have been around since the*

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> *1970s, pedagogical agents did not appear until the late 1980s. Pedagogical agents have been designed to produce a range of behaviours that include the ability to reason about multiple agents in simulated environments; act as a peer, co learner, or competitor; generate multiple, pedagogically appropriate strategies; and assist instructors and students in virtual worlds" (Koschmann, 1996).*

This approach was developed further in authoring agents discussed later in this paper.

Authoring agents: Learning Design Support Environment (LDSE)

The educational scenario requires continuous changes in the adoption of educational models and tools. Diana Laurillard with collaborators is the project leader of Learning Design Support Environment (LDSE) and she designs the basic functionality and pedagogical input of LDSE (https://sites.google.com/a/lkl.ac.uk/ldse/Home).

This research discovers how to use digital technologies to support teachers in designing effective technology-enhanced learning (TEL). Teachers will be required to use progressively more TEL and the teaching community should be at the forefront of TEL innovation. Thanks to the use of TEL the development of new knowledge, in this case about professional practice, should be carried out in the spirit of reflective collaborative design. The same technologies that are changing the way students learn can also support teachers' own learning and teachers' design.

The LDSE project aims to fill the gap in research that currently exists between technology, design and learning for teachers. I-tutor project is taking this LDSE model when designing the authoring agent of the I-tutor robot.

Semantic WEB and IIS

Core technologies

Another approach to IIS (Intelligent Instructional Systems) is the approach of Semantic WEB. In order to understand the structure of the content of the web based learning material, special technical solutions have to be used. Koper (2004) collects the core technologies:

- Unified Modelling Language (UML) (Booch, Rumbaugh & Jacobson, 1999; Fowler, 2000). UML provides a collection of models and graphs to describe the structural and behavioural semantics of any complex information system;
- XML and XML Schema's (XML, 2003), derived from SGML (ISO 8879). These are tools used to go beyond the fixed, page structure oriented vocabulary that HTML provides;
- RDF and RDF-Schema is the metadata approach from the W3C (RDF, 2003). It does not structure the syntax of the data, but defines semantic meaning for data on the web;

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- Topic Maps (ISO/IEC 13250:2000), provide an alternative technology to RDF (Maicher & Park, 2005). Topic maps define arbitrarily complex semantic knowledge structures and allow the exchange of information necessary to collaboratively build and maintain indexes of knowledge;
- OWL Web Ontology Language. According to Mc Guinness and van Harmelen (2004), ontology languages provide greater machine interpretability of Web content than that supported by XML, RDF, and RDF-Schema;
- Latent Semantic Analysis – LSA, (Landauer & Dumais, 1997). The approaches mentioned above require humans to provide the semantic meaning by using a machine interpretable coding scheme;
- Software Agents (Axelrod, 1997; Ferber, 1999; Jennings, 1998). One of the basic technologies that can exploit the coded semantics on the web is software agents.

It seems to me that for describing ontologies we need for IIS OWL will be the most suitable tool. Among many other possibilities that semantic web may offer, Instructional design can also benefit from that Devedzic describes: "Intelligence of a Web-based educational system means the capability of demonstrating some form of knowledge-based reasoning in curriculum sequencing, in analysis of the student's solutions, and in providing interactive problem-solving support (possibly example-based) to the student, all adapted to the Web technology" (Brusilovsky & Miller, 2001).

Those semantic technologies mainly OWL and LSA were widely used in building I-tutor robot.

Standard vocabularies

Looking at issues that would be interesting in AI and ID, Devedzic explains:

„Authors develop educational content on the server in accordance with important pedagogical issues such as **instructional design** and human learning theories, to ensure educational justification of learning, assessment, and possible collaboration among the students. The way to make the content machine-understandable, machine-processable, and hence agent ready, is to provide semantic mark up with pointers to a number of shareable educational ontologies" (Devedzic, 2004).

He also highlights (like Mizogouchi & Bordeau, 2002) the problem of ID ontology structures also from linguistic and structural differences point of view:

"One of the reasons why standard ontologies that should cover various areas and aspects of teaching and learning are still missing is the lack of standard vocabulary in the domain of education and instructional design. There are several working groups and efforts towards development of an official standard vocabulary. Examples include the IEEE Learning Technology Standards Committee (http://www.ieeeltsc.org:8080/Plone), Technical Standards for Computer-Based Learning, IEEE Computer Society P1484

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(http://www.computer.org/portal/web/guest/home), IMS Global Learning Consortium, Inc. (http://www.imsproject.org), and ISO/IEC JTC1/SC36 Standard (http://www.sc36.org:8080/). However, there is still a lot of work to do in that direction. Hence many structural, semantic, and language differences constrain reusability of applications produced by current tools" (Devedzic, 2004).

He criticizes Murray (1998), Mizoguchi and Bourdeau (2002) because „Ontology-development tools that have resulted from these efforts have implemented a number of important ideas, but did not support XML/RDF encoding of ontologies and consequently were not Semantic Web-ready" (Devedzic, 2004).

He lists then the possible standards that bring us closer to the solution:

> *„The statement of purpose of the project is very detailed, and includes issues like search, evaluation, acquisition, and utilization of Learning Objects, sharing, exchange, composition, and decomposition of Learning Objects across any technology supported learning systems and applications, enabling pedagogical agents to automatically and dynamically compose personalized lessons for an individual learner, enabling the teachers to express educational content in a standardized way, and many more. All of this is actually the essence of teaching and learning on the Semantic Web. P1484.14 supports P1484.12 by proposing and developing techniques such as rule-based XML coding bindings for data models. Finally, it should be noted that such efforts are related to more general standard proposals for ontology development. People involved with the IEEE SUO (Standard Upper Ontology) project 1600.1 (http://suo.ieee.org) are trying to specify an upper ontology that will enable computers to utilize it for applications such as semantic interoperability (not only the interoperability among software and database applications, but also the semantic interoperability among various object-level ontologies themselves), intelligent information search and retrieval, automated inferencing, and natural language processing" (Devedzic, 2004).*

Further development trends are envisaged by Devedzic (2004) which might worth our attention: "An important research trend in the Semantic Web community that may support the idea of gradually evolving educational ontologies as well is ontology learning (Maedche & Staab, 2001). The idea is to enable ontology import, extraction, pruning, refinement, and evaluation, giving the ontology engineer coordinated tools for ontology modelling. Ontology learning can be from free text, dictionaries, XML documents, and legacy ontologies, as well as from reverse engineering of ontologies from database schemata."

In the time framework of I-tutor, and because of the multi-language approach of the semantic agent, a semantic database is built, and helps the tutor and students, but a semantic agent will be developed in a further development phase.

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Implementation of theory in I-tutor design

I-TUTOR acts as an agent community, as stated in the Project Description: the main source of inspiration for this architectural choice are Bentivoglio et al. (2010) and Pilato et al. (2008). In this works, the main focus was student tutoring, and the agent community was designed to support a conversational agent aimed at dialoguing with the student to assess her learning, and to stimulate her self-reflection processes. Artificial Intelligence was mostly encapsulated in such an agent to support dialogue with Natural Language Processing (NLP) and reasoning techniques.

The specification extraction process altered the original design, which was mostly cognition-oriented, while inserting considerations and scientific results from the Education Science discussed earlier. The current I-TUTOR design takes into account also the other actors involved in the learning process using a Virtual Learning Environment (VLE). As a consequence, a suitable arrangement of the agents to be designed has been devised.

I-TUTOR specifications

I-TUTOR is intended to provide intelligent support to the three main actors involved in the learning process through a VLE:

- The instructional designer
- The tutor
- The student.

All the roles are involved in intense cognitive processes so "intelligence" in I-TUTOR has to be intended in support of their decisions. The intelligent mechanisms to be implemented derive from both functional and non-functional specifications along with time constraints related to the project schedule, and duration. In what follows, such specifications are listed.

Functional specifications put into evidence that the main components to be implemented in I-TUTOR are:

- Monitoring,
- Profiling,
- Alerting,
- Learning Design,
- Visualization,
- Semantic Support.

The two relevant agents of the functions of I-TUTOR for this paper are the Learning Design Agent and the Semantic support (yet not an agent).

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Learning Design Agent

The Learning Design relies on the learning design ontology derived purposely from the process described by Dana Laurillard, and integrated by UNIMC. The same partner is in charge to engineer the related OWL document. The learning design process is arranged in "modules" that are further split into "sessions" (i.e. lessons) while each session consists of "activities".

The core of the ontology is the "didactical device" that is used to accomplish an activity in the VLE. A didactical device consists of a "tool" and a "content". A tool owns a "title", some involved "people", and a "time" for being used to accomplish the task. A content owns some "subject", has some "objectives", and has "finalities". Finally, a "learning path" is a pathway along devices on the tool side, while a "content path" is a pathway along devices on the content side. Content and learning paths have to be displayed to the student.

The learning design methodology consists in designing the whole module, which has its macro-objectives, a description, and a set of keywords. A suitable data structure will hold the module global information. For each module, the session, and activities are instantiated each with its micro-objectives, the subject, and the finalities. Education Science provides ways for building correspondences between macro- and micro-objectives. The key idea is to have the module information structure linked with the corresponding activities and devices via macro- to micro-objectives mapping.

The Learning Design performs the following main functions:

- Takes the learning design ontology as its input.
- Produces a XML fram-like description of the alerting events.
- Has an author tool to implement the learning design methodology both at module and activity level; such a tool is integrated seamlessly with the Moodle counterpart.
- Performs macro- to micro- objectives mapping at least via a suitable look-up table.
- Stores either entire design structures or single patterns.
- Extracts co-occurrence rules, and suggests the most used patterns to the designer.
- Sends all the information to the Visualization.

Semantic Support

Semantic support is just a set of text analysis functions to accomplish the language-oriented tasks in the Profiling and in the Learning Design. We are using:

- Stemming,
- Stop-words removal,
- Keywords extraction,
- Topic categorization,
- NER,
- Latent Semantic Indexing.

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Conclusions

The first version of I-tutor is already built and ready for piloting in different educational settings. By the end of the year modifications and adjustments to the I-tutor will be made, and will be offered not only to the project partners and piloting courses, but for the wider Moodle community to use and develop further. During the project lifecycle detailed valorisation plan will be developed.

Reference

1. Axelrod, R. (1997). The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration. Princeton Press. Princeton.
2. Bentivoglio, C.A.; Bonura, D.; Cannella, V.; Carletti, S.; Pipitone, A.; Pirrone, R.; Rossi, P.G.; Russo, G. (2010). Intellligent agents supporting user interactions within self regulated learning processes. In *Je-LKS Journal of e-Learning and Knowledge Society, 6(2)*, (pp. 27-36), ISSN: 1826-6223.
3. Bloom, B.S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. In *Educational Researcher. 13*, (pp. 4-16).
4. Booch, G.; Rumbaugh, J.; Jacobson, I. (1999). *The Unified Modeling Language User Guide.* Addison-Wesley. New York.
5. Bramucci, A. and Zarka, D. (2012). The Role of Instructional Design and Learning Design in Intelligent Tutoring Systems. In G. Paviotti, P.G. Rossi & D. Zarka (eds.), *Intelligent Tutoring Systems: An Overview,* (pp.113-153). Pensa MultiMedia Lecce. ISBN 978-88-6760-048-9.
6. Branson, R.K.; Rayner, G.T.; Cox, J.L.; Furman, J.P.; King, F.J.; Hannum, W.H. (1975). *Interservice procedures for instructional systems development.* (5 vols.) Florida State Univ Tallahassee Center for Educational Technology. Miami.
7. Brusilovsky, P. and Miller, P. (2001). Course Delivery Systems for the Virtual University. In T. Tschang & T. Della Senta (eds.), *Access to Knowledge: New Information Technologies and the Emergence of the Virtual University,* (pp. 167-206.). Elsevier. Amsterdam. http://www.sis.pitt.edu/~peterb/papers/UNU.html
8. Davis, W.K.; Nairn, R.; Paine, M.E.; Anderson, R.M.; Oh, M.S. (1992). Effects of expert and non-expert facilitators on the small-group process and on student performance. In *Academic Medicine, 67*, (pp. 470-474).
9. Devedzic, V. (2004). Education and the Semantic Web. In *International Journal of Artificial Intelligence in Education, 14*, (pp. 39-65).
10. Ferber, J. (1999). *Multi-agent Systems.* Addison-Wesley. New York.
11. Fowler, M. (2000). *UML Distilled: A Brief Guide to the Standard Object Modeling Language.* Jacobson. Hamburg.

12. I-Tutor project website: http://www.intelligent-tutor.eu
13. Jennings, N.R. (1998). A Roadmap of Agent Research and Development. In *Autonomous Agents and Multi-agent Systems, 1(1)*, (pp. 7-38).
14. Koper, R. (2004). Use of the Semantic Web to Solve Some Basic Problems in Education: Increase Flexible, Distributed Lifelong Learning, Decrease Teachers' Workload. In *Journal of Interactive Media in Education, 6*. Special Issue on the Educational Semantic Web, (pp. 1-9).
15. Koschmann, T. (1996). Paradigm Shifts and Instructional Technology: An Introduction. In T. Koschmann (ed.), *CSCL: Theory and Practice of an Emerging Paradigm,* (pp. 1–23). Mahwah, NJ: Lawrence Erlbaum Associates.
16. Landauer, T.K. and Dumais, S.T. (1997). A solution to Plato's problem: The Latent Semantic Analysis theory of the acquisition, induction, and representation of knowledge. In *Psychological Review, 104*, (pp. 211-240).
17. Learning Design Support Environment website: https://sites.google.com/a/lkl.ac.uk/ldse/Home
18. Lepper, M.R.; Woolverton, M.; Mumme, D.; Gurtner, J. (1993). Motivational techniques of expert human tutors: Lessons for the design of computer-based tutors. In S.P. Lajoie & S.J. Derry (eds.), *Computers as cognitive tools*, (pp. 75-105). Lawrence Erlbaum Associates. Hillsdale.
19. Maedche, A. and Staab, S. (2001). Ontology learning for the Semantic Web. In *Intelligent Systems, IEEE, 16(2)*, (pp. 72-79), http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=920602&contentType=Journals+%26+Magazines&sortType%3Dasc_p_Sequence%26filter%3DAND%28p_IS_Number%3A19905%29
20. Maicher, L. and Park, J. (2005). *Charting the Topic Maps Research and Applications Landscape.* Springer. Berlin.
21. Mc Guinness, D. and van Harmelen, F. (2004). OWL web ontology language overview. In *W3C recommendation. 10*, (p. 3).
22. Merrill, M.D.; Drake, L.; Lacy, M.J.; Pratt, J. (1996). Reclaiming instructional design. In *Educational Technology. 36(5)*, (pp. 5-7).
23. Mizogouchi, R. and Bordeau, J. (2000). Using Ontological Engineering to Overcome Common AI-ED. In *International Journal of Artificial Intelligence in Education, 11*, (pp. 107-121).
24. Mizogouchi, R. and Bordeau, J. (2002). Collaborative Ontological Engineering of Instructional Design Knowledge for an ITS Authoring Environment. In *ITS '02 Proceedings of the 6th International Conference on Intelligent Tutoring Systems*, (pp. 399-409). Springer. Berlin.

ISBN 978-963-89559-3-7

25. Murray, T. (1998). Authoring Knowledge-Based Tutors: Tools for Content, Instructional Strategy, Student Model, and Interface Design. In *The Journal of the Learning Sciences, 7(1)*, (pp. 5-64).

26. Pilato, G.; Pirrone, R.; Rizzo, R. (2008). A KST-Based System for Student Tutoring. In *Applied Artificial Intelligence, 22(4)*, (pp. 283-308), ISSN: 0883-9514, DOI: 10.1080/08839510801972785.

27. Poole, D.; Mackworth, A.; Goebel, R. (1998). *Computational Intelligence: A Logical Approach.* New York: Oxford University Press. ISBN 0-19-510270-3.

ISBN 978-963-89559-3-7