Advancement of MOOCs with Learning Pathways

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Abstract:
In this paper, educational and technical challenges in the field of Massive Open Online Courses (MOOCs), such as cultural adaptation, consideration of learning habits or the efficient construction of educational content, are outlined. We argue that learning pathways in combination with learner-centered metadata are optimal methods to meet those challenges and hence optimize learning efficiency and learning experience substantially by creating personalized learning recommendations and feedback. This is illustrated from a conceptual and technological perspective, as is currently in development in the EU-project INTUITEL. We believe that this approach not only opens up new possibilities for MOOCs, but also provides a variety of new dimensions for eLearning in general.

Keywords:
MOOC, eLearning, Learning Pathways, Reasoning, Semantic Web

Introduction

Massive Open Online Courses (MOOCs) involving thousands of learners via the internet are currently a major topic in technology enhanced learning (TEL). Traditionally, only a limited number of students can be taught face-to-face. With this new approach, it is possible that inquisitive learners from all over the world can participate in the lectures of proven experts. As formulated enthusiastically in the New York Times, "[e]ven in a remote developing country like Mongolia […] you can find high-school students tuning into courses from American universities like M.I.T., Harvard and Berkeley" (Pappano, 2013). MOOCs provide one solution to the world's educational problems, especially in the context of Open Education Resources (OER), which are promoted by the UNESCO (UNESCO, 2012).
But even if we consider this proposition as truth for now, the MOOC form of teaching leads to new technical and didactical challenges that concern fundamental aspects of learning: language, the cultural background of learners, as well as individual learning habits and learning discipline – to mention some of the most prominent ones. Dropout rates of 90% are commonly observed during a MOOC (Rivard, 2013), and to our knowledge this is mainly caused by the anonymity of MOOC learning. The first question dealt with in this paper is therefore, how MOOC learning can be made more personalized, human-centered and interactive by a technologically enhanced Learning Management System (LMS).

MOOCs also have the disadvantage that full-fledged courses with high quality content are expensive to produce, difficult to maintain and almost impossible to adapt to individual needs. The second aspect of this paper therefore concerns Small Open Educational Resources (SOER) – ranging from a single instructive text or picture to high resolution video clips: How may one connect such SOER together along predefined learning pathways in order to create a MOOC-like course.

In order to address these points, we will first summarize the challenges of MOOCs. We then present the EU project INTUITEL, whose educational and technical core elements provide a consistent answer to these challenges introduced. It is expected, that the INTUITEL concepts will not only provide a better overall learning experience and increase completion rates, but will also open new opportunities to combine the advantages of MOOCs and SOERs.

Educational and technical challenges of MOOCs

MOOCs are reliant on the provision of high quality learning material, even more than in common eLearning, because of the diversity of learners. Since the direct interaction with teaching staff is hardly possible, clarifying problems is complex and the material itself should hence be of such a high quality that those issues do not occur in the first place. In particular the cultural and educational backgrounds of the students make the provision of knowledge in a one-size-fits-all manner questionable. Yet the various preferred teaching methods which are practiced in the different school systems all over the world, demonstrate how versatile prerequisites and learning habits are. While, for instance, "Chinese classrooms tend to be more structured and authoritarian than classrooms in the West, [...] American schools try to encourage critical thinking skills and student interaction with teachers" (Lockette, 2006). If one applies this directly to eLearning material, it is very likely that two fundamentally different courses result from these different 'boundary conditions'. Under the premise that students need time and effort to adapt to the differences resulting from culturally motivated learning styles, the net learning time is reduced and efficiency is impaired.

Consequently, if the learning material is not provided in a suitable (i.e. context dependent) and didactically meaningful way for the individual student, the basic transfer of knowledge is already a problem. In our experience, the question of who has authored the course then becomes less relevant. Three fundamental questions related to effective online learning thus need to be considered:

1) How should an online course be structured to be didactically meaningful under different educational boundary conditions?
2) How could one re-use learning material by adapting it to such different boundary conditions?
3) What do Learning Management Systems need to provide in order to achieve this?

In the European Commission (EC) project INTUITEL, the answer to these questions is the processing of learning pathways and metadata to customize the learning process to the needs of learners depending on their individual contexts and achievements. This poses some significant challenges for the eLearning providers, because the provision and individualization of traditional learning material (e.g. as materialized in books and lectures) in this style is technically, structurally and conceptually complex to realize. INTUITEL takes care of these aspects and allows addressing the learning requirements of each particular student and consequently better guide them in relation to their learning goals.

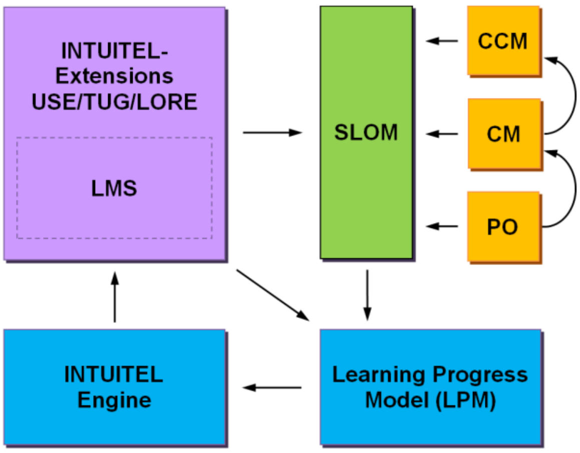
In the following, we assume that a MOOC is constructed of a set of knowledge objects. They may be accessed separately and in different order according to some predefined sequence we call a learning pathway. The individualization we want to achieve then consists of selecting an order of the knowledge objects based on considering all the aforementioned aspects for an individual learner – and possibly very different from one of the predefined orders.

INTUITEL achieves this for five different leading eLearning platforms (Clix, Crayons, eXact LCMS, ILIAS and Moodle), and has already shown in a publicly available white paper how to write such add-ons in virtually every Learning Management System. The INTUITEL consortium furthermore provides a format specification on the basis of Semantic Web technologies, allowing the didactical enhancement of learning material in those platforms in a non-intrusive way. This ultimately enables the deduction of learning recommendations and feedback for each individual learner.

Technical approach of INTUITEL

The INTUITEL system consists of five main components: (i) a lightweight extension of the host application giving access to its data and user interface. The respective specification is open and can be applied to every type of learning platform. It is based on a set of REST[1] services to exchange learner related data. On one side, the learning platform provides data about the learner and on the other side, INTUITEL returns learning recommendations and feedback messages[2] in natural language. Depending on the platform, this requires only minimal additions, which has been demonstrated by the INTUITEL consortium in multiple proof of concept implementations. The respective realizations for ILIAS and Moodle are open source and usable as blueprints for other systems.

Figure 1: Simplified component layout



(ii) The Pedagogical Ontology (PO) is based on Meder's web-didactics (Meder, 2006) and the insights gained from the L3-project (Leidig, 2001). It contains the vocabulary and relations necessary for enhancing the learning material with didactical and technical metadata. The separation of topical and content knowledge not only allows implementing learning pathways on different levels of abstraction, but also encourages "teachers and learners […][to] play with educational concepts" (Swertz et al., 2013).

(iii) The Semantic Learning Object Model (SLOM) describes how learning material needs to be annotated in order to be interpretable by the INTUITEL system. This is done by describing domain knowledge (Cognitive Map, CM) and courses (Cognitive Content Map, CCM) with the terms and relations from the Pedagogical Ontology. The main advantage of this approach is that the original data remains unchanged, because the INTUITEL-specific metadata is only linked to the source material. Consequently, the LMS and other tools do not need to be adapted in an INTUITEL-enabled system. This reduces the burden for developers and users, since they can keep using the software as they normally do. To further enhance usability, INTUITEL will also provide an editor and transformation modules for SCORM, IMS-LD, and Semantic MediaWiki to enter and automatically determine the needed metadata.

(iv) The INTUITEL back-end aggregates the required information and uses it to create learning recommendations and feedback. This is carried out in a multi-stage process, by the Learning Progress Model (LPM) and the INTUITEL Engine, which is described in more detail below.

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[1] Representational State Transfer – see http://www.ics.uci.edu/~fielding/pubs/dissertation/rest_arch_style.htm

[2] The feedback message channel is bidirectional, i.e. the INTUITEL system can initiate a dialogue with the learner to not only give recommendations but to also obtain additional user input.

(v) The INTUITEL communication layer (CL) interconnects the previously described components and manages message distribution. Since all exchanged data is based on XML, the data transmission is relatively simple (i.e. HTTP). However, complexity quickly rises when the system has to manage a huge number of learners in parallel – as it is the case with MOOCs. To still ensure that response times are short, the communication layer will be available in two versions. The basic CL is free, open and sufficient for general usage scenarios, whereas the advanced CL provides more features and is optimized for distributed systems.

Reconstructing learning processes

Before discussing how INTUITEL meets the fundamental task of all intelligent tutoring systems, namely "to simulate a human tutor's behavior and guidance" (Koedinger & Tanner, 2013), one should first determine how the needs of students are assessed to provide this kind of support in the first place. While this is already a non-trivial challenge in traditional cognitive science and educational theory, the application of this principle poses further complexity in TEL.

Within the INTUITEL project we believe to have found a pragmatic way to reconstruct the learning process and reduce the complexity that usually arises when mimicking human thinking. There are three main elements in a typical real life teaching situation: (i) the person trying to obtain the knowledge, (ii) the person mediating the knowledge and (iii) the knowledge itself. In the process of equipping the learner with this knowledge (i.e. by following a certain learning pathway), the teacher also learns about the previous knowledge of the learner and also receives feedback (direct and indirect). Four information sources are important when solving learning problems in this situation:

(i) The learning content – What has to be learned?
(ii) The learner history – What has already been learned?
(iii) The learning environment – What are the temporal, spatial and physical parameters?
(iv) The learner – What are the characteristics of the person?

On this basis, the actual problem can be split into smaller and easier manageable elements are all collectable in an INTUITEL-enabled system. The learning content for INTUITEL will be heavily annotated with metadata and structured along different semantic views of the material (like e.g. physical or thematic views) and stored in the SLOM format. Information about the learner history is obtained from the LMS and kept in the INTUITEL system. The learning environment may be inferred via the user interface (e.g. by using JavaScript) and the capabilities of the access device itself. The characteristics of the learner are bit more complex to acquire, but also identifiable with the INTUITEL-approach. Either the available data suggests these characteristics, or the learner is directly asked for them by initiating a dialogue.

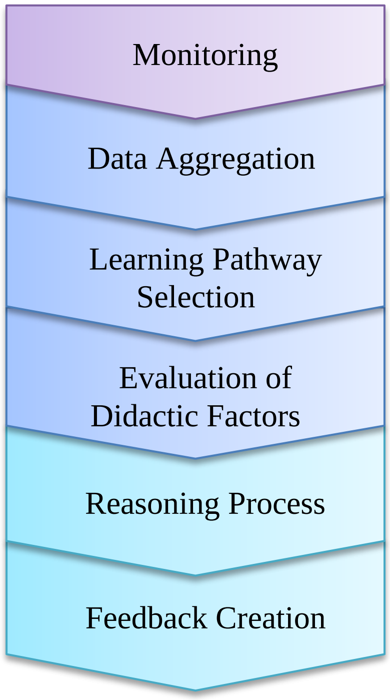
Given that all of this information is accessible, the question remains how the data should be used to come to the respective conclusions. INTUITEL approaches this problem by using *didactic factors*. These are symbolic statements that have a distinct meaning for the learning process. They are defined once, but are calculated for each learner individually on the basis of the previously described information sources. By combining them with the learning pathway information, it is possible to deduce that a certain knowledge object is better for the learner than another one. Furthermore, it is possible to state why this is the case (e.g. because it is age-appropriate, has a suitable difficulty level, etc.).

This method is a direct extension of the previously described real life learning situation and resembles a factual decision of the learning staff. When a tutor knows that it would be good to proceed with knowledge object X or Y in order to stay on the thematic track, he or she (subconsciously) assesses the current conditions. If it is concluded that requirements are met that make X more suitable than Y, the decision is obvious. Take, for example, the scenario that the tutor notices that the learning speed has decreased in the recent learning steps. If those steps have mainly been concerned with theoretical knowledge, proceeding with examples and not with more theoretical material, could increase the learning speed again. The challenge is thus not to mimic thinking itself, but to reasonably cluster the available data (i.e. identify didactic factors) and to combine them intelligently.

Automatic recommendation and feedback creation

In INTUITEL, this is achieved in a multi-stage process with two main components, the Learning Progress Model and the INTUITEL Engine. Technologically, they are implemented by using the descriptive power of OWL and the flexibility of object oriented programming with Java, making it possible to exploit the available information as best as possible.

Figure 2: Back-end workflow



The LPM acts as a data aggregation and pre-processing entity which supplies the INTUITEL Engine with the relevant information. Basic trigger in this process is the monitoring of learner behavior[3], i.e. the moment when a learner begins a new learning step. If such an incident is recorded, a personalized recommendation and feedback creation process is started.

As a first step, the relevant situational and learner-specific data is requested from the learning platform and the domain and content information is retrieved from the corresponding SLOM repository[4]. Together with the previously stored data (e.g. past recommendations and beforehand requested information), the most suitable learning pathways and the didactic factors are determined.

INTUITEL takes two approaches to finding optimal learning pathways for a learner: an interactive and a technological one. Firstly, it may carry out an interactive dialogue with each learner. In this case, teachers can add notes and describe for whom a particular pathway is most suitable. This makes it possible for learners to make an informed choice. Although this initially provides a decent starting point, it leaves room for improvements, since self-assessments are commonly qualitatively limited (see e.g. Davis et al., 2006). It is consequently less reasonable to rely solely on the fact that (i) the learner has estimated his or her current standing and learning style correctly and that (ii) the description of the learning pathway is formulated in a way that is comprehensible for each reader. INTUITEL thus implements a data-driven approach that allows evaluating the respective data programmatically[5]. With this method, the system can automatically come to conclusions whether the current selection is optimal, or if the learner's behavior indicates that another learning pathway would be more suitable. Not only does this help the learners in the learning process, it also enables them to self-reflect and thus increases their metacognitive skills.

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[3] It should be noted at this point that the INTUITEL system is capable of working with IDs only, i.e. the platform does not need to disclose who the learner in scope is. It is thus possible to fully anonymize the data in the INTUITEL system in order to reduce possible privacy issues to a minimum.

[4] SLOM repositories are specialized data storages for SLOM files that are developed in context of the INTUITEL project. Planned key features are, amongst others, that they will be accessible via the web and provide SLOM-specific data retrieval features.

[5] Currently, two different algorithms are already implemented. Both analyze learning pathways and learning history on the basis of an n-dimensional hypercube model. A respective publication, which describes this in more detail, is in the writing and will be published in due time.

The calculation of the didactic factors is an iterative process that inspects each factor for each learner individually. The basic definitions of the factors and their value ranges exist as an individual ontology, which is interpreted by the LPM. A factor can thereby virtually be anything that is determinable with the available data, expresses some kind of relevance for creating learning recommendations or feedback messages, and fits into the following evaluation schema. This method allows the incorporation of various aspects into eLearning, like e.g. motivation (cf. Erriquez & Grassi, 2008), sleep-deprivation (cf. Walker & Stickgold, 2004) or emotions (cf. Bower, 1981). Especially in the context of MOOCs, where usually no direct interaction between the teacher and learner happens, this approach could dramatically increase the learning experience and make the approach more learner-centered.

All these data are afterwards merged into a single ontology with the original SLOM data and forwarded to the INTUITEL Engine. This component is a combination of a set of Java modules and standard OWL-reasoners (like e.g. FaCT++[6] or HermiT[7])[8]. Its task is to analyze the provided individualized ontology in order to identify the most suitable knowledge objects with regard to the most suitable learning pathways and the current situation as expressed by the didactic factors. It then generates semantic queries and starts the most efficient reasoners for the specific query. For this, INTUITEL builds on the results and insights of the THESEUS project (BMWi, 2008) and in particular the HERAKLES Reasoning Broker (Bock et al., 2009)[9]. The output of this iterative procedure is then interpreted by the Recommendation Rewriter, which revises them to create the final learning recommendations and also generates natural language messages for the learner, if appropriate.

Strengthening the character of MOOCs

This multi-layered procedure, as carried out in the INTUITEL back-end, allows a very high level of individualization. The learning progress of each learner is evaluated gradually in respect to multiple aspects. This not only allows to select the most suitable learning pathway for each student, but also to determine which of the routes on these pathways fits the individual cultural and educational needs of the learner. Didactic factors can furthermore be used to guide learners in regard to fine-granular aspects and thus consider the given individual boundary conditions. Especially in the context of multicultural course participants, this approach unfolds its benefits, by including personal and also cultural preferences. Because of its highly modular architecture, the system moreover leaves room for future insights of cultural dependent learning. These improvements can be to consider the target audience and then defining learning pathways accordingly, as well as integrating diversity aspects in the automatically performed educational deductions.

Another aspect is that the learning material is only linked with the SLOM data and not necessarily merged. MOOC-creators are thus not restricted in their choices of what learning material they provide and in which style they do it. They only need to add further information to it in a subsequently following step. This approach preserves the high level of freedom for course creation currently demanded by authors. Since this pattern is also applied when learning platforms are extended with INTUITEL features, the other functions of the eLearning software are not impaired. Students need to only minimally accustom themselves with the new features of their LMS. Because INTUITEL is furthermore not limited to a certain platform, it emphasizes the open character of MOOCs.

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[6] See http://owl.man.ac.uk/factplusplus/
[7] See http://hermit-reasoner.com/
[8] To optimize the performance, the development or adaption of reasoners for specific tasks is in discussion.
[9] See also: http://sourceforge.net/apps/mediawiki/herakles/index.php?title=Main_Page

MOOCs from Small OER

The Semantic Learning Object Model allows storing annotations alongside with the learning content. Consequently, the annotated content becomes re-usable in the INTUITEL system, because they can be interpreted outside of their local context. An INTUITEL-enabled course is not limited to its own ("local") learning content, but may involve such content from other courses or simply from the Web.

Given that this is extended to a (possibly decentralized P2P-) network of SLOM repositories, renowned authors from all over the world can link their material via URIs and provide their learners with a huge knowledge space. It is conceivable that such a knowledge space can attract as much learners as one of the current MOOCs – but more flexibly so and with an almost unlimited individuality. We can leave it open whether one should call this a "MOOC" then.

A course designer – or many of them – can contribute to this knowledge space not only by adding new learning content. They can also contribute a new Cognitive Content Map (CCM), which defines new learning pathways through this knowledge space. Cultural adaptation is only one of the possibilities such opened. Another possibility is to keep such a course up to date: One may add how recent a knowledge object is to the set of didactical factors – and then automatically receive recommendations to use more recent learning content with higher priority. At the same time, this allows an innovative learning pathway: adding new learning content while keeping the old one allows learning about the history of this domain of knowledge. Last but not least, we mention two further options: (i) creating an international federation of eLearning content providers and (ii) finding similar learning material via its SLOM properties.

Opportunities for learning analytics

Learning analytics starts with logging what the users do in the LMS. A semantic model for the learning content and its handling by a semantic engine, as suggested by INTUITEL, may however produce a vast amount of highly detailed data on the learning process. The visions in this regard are far ranging and pioneers in this field, like Sebastian Thrun, predict that the analysis of such large-scale educational data could "be the biggest revolution in education since the Middle Ages" (Grant, 2013).

MOOCs – whether "original MOOCs" or distributed courses as described in the previous section – look especially promising in this context because of their large participation. Not only does this provide a diverse data basis, but it also aggregates the respective information in a digital form and over a long term, without the need to directly interfere in the process. The only limitations in this regard are the sensorial capabilities of the platform and quality of the collected data.

Summary

In this paper, we outlined a way to make MOOCs more suitable for a greater variability of learning needs, by semantically annotating its parts and running them in a semantically enhanced environment. The EC-project INTUITEL has the potential to contribute to important key aspects of MOOCs, e.g. how to enhance courses in a didactically sound and effective way, how to add semantic interoperability and how eLearning platforms can be of assistance in that regard. Such a semantic reconstruction of current MOOCs will, in our estimate, resolve the current problems of high dropout rate in MOOCs.

We furthermore outlined how complex and large courses may be constructed from Small OER, thereby resolving the problems of maintainability and adaptability of current MOOCs. The INTUITEL system here serves as the "glue" integrating various learning content into a greater knowledge space.

By providing the information on the learning process in a suitable format, INTUITEL also opens the doors for other technologies like learning analytics and data mining in the educational sector. With the insights that can be gained from a data driven perspective, this could result in new didactical approaches and thus enhance education in general.

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