Towards an Outcome-based Discovery and Filtering of MOOCs using moocrank

Israel Gutiérrez-Rojas, Derick Leony, Carlos Alario-Hoyos, Mar Pérez-Sanagustín and Carlos Delgado-Kloos

Department of Telematic Engineering, Universidad Carlos III de Madrid,

Av. Universidad, 30, 28911, Leganés (Madrid), Spain

Abstract: *The recent outbreak of massive open online courses (MOOCs) is empowering people around the world to satisfy their learning needs. More and more universities are offering MOOCs in online platforms such as Coursera, edX or Udacity, and thus, the catalog of courses to choose from is largely increasing. With the growth of available MOOCs, there is a need for approaches to facilitate the discovery of courses and filter those that best meet the learning objectives of each learner. This article presents moocrank, a web application that maps MOOCs from different platforms with learning outcomes, allowing learners to discover the most suitable MOOCs for their profile and learning objectives. This article presents and discusses the requirements of moocrank as well as the first prototype of the application and next steps.*

Introduction

2012 was declared by The New York Times "the year of the MOOC" (Pappano 2012), since the number of massive open online courses (MOOCs) offered by Higher Education institutions greatly increased. With the coming of the MOOCs there is a plethora of learning opportunities open to any learner all around the world (Cooper & Sahami 2013). Nevertheless, the MOOC offerings are so large that sometimes it is difficult to find an appropriate path across the vast amount of learning opportunities. It is not easy for learners to discover new MOOCs that meet their personal learning objectives, taking also into account previous achievements and knowledge (Boyatt & Sinclair 2012). One of the reasons that hinder the discovery and selection of new MOOCs is that major platforms do not use the same taxonomy to describe the learning outcomes (LO) that students achieve once accomplishing the courses.

The European Qualifications Framework defines learning outcomes as "statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence" (http://ec.europa.eu/eqf/terms_en.htm). Several European research projects have worked with LO, finding relationships between open educational resources (OER) and learning outcomes (Kalz et al. 2010). Among these projects ICOPER (http://www.icoper.org/) stands out, whose main objective was to define best practices in the usage of standards and specifications in competence-based education. One of the developments carried out within the ICOPER project was the Open ICOPER Content Space (OICS), a tool that allowed the outcome-based search of open educational assets (learning designs, assessments, etc.) harvested from several OER platforms. This project classifies learning outcomes as intended LO (i.e. those that a learner wishes to get), and achieved LO (i.e. those already acquired by the learner). This is the terminology adopted throughout this paper.

Another related initiative at the European level that addresses open educational resources (OER) is the recent Opening Up Education initiative (http://www.openeducationeuropa.eu), which intends to be the European reference site for searching open educational assets, sharing experiences of usage among European practitioners, and aggregating related research papers and news. Recently, this site for the first time included MOOCs as open educational assets, as well as a scoreboard indicating the number of available MOOCs in Europe per country (http://www.openeducationeuropa.eu/en/european_scoreboard_moocs). However, the Opening Up Education initiative does not take into account learning outcomes and how these outcomes can be used to link OER with learners' objectives.

The aim of this work is to take advantage of the research carried out in previous European projects like ICOPER about outcome-based education and OER, applying the results to a particular kind of open educational asset: MOOCs. In this context, the research objective is to give some order and structure to the vast number of MOOCs that are currently available, associating LO to MOOCs following established taxonomies proposed by recognized institutions such as the ACM and IEEE-Computer Society. So, learners can take control of their own learning path when looking for new MOOCs to update their knowledge on particular areas. moocrank allows learners to discover courses that meet their profile and align with their intended LO. Further, moocrank allows learners to annotate courses with information about the achieved LO, collaboratively enriching the discovery of MOOCs.

The rest of the paper is structured as follows: the next section describes the methodology followed in this work.

Then, the problem statement and initial hypothesis are clearly defined. A set of requirements that lead the design of a system for supporting users in the discovery of MOOCs is discussed immediately afterwards. The following section presents the design and preliminary implementation of moocrank, a tool that is being developed following the aforementioned requirements. Finally, the last section discusses the requirements and current implementation of moocrank, providing some insights about the next steps with a special emphasis on how to include a recommender module.

Methodology

In this research project we follow a design-based research approach, as described in Wang and Hannafin (2005). We chose this methodology because its features are very aligned with the project objectives: we work on a real-world problem, iteratively searching for a solution to that problem; the research objectives can be redefined during the project; and we are evaluating the results making use of mixed methods.

As a first step, we employ a survey and state-of-the-art literature to justify the problem we are trying to solve: due to the great variety of MOOCs offered, it is difficult to find courses aligned to learners' intended LO. Once justified that this problem exists, a series of initial requirements are defined in order to lead the design of a system that addresses the research problem. The definition of these requirements is based on previous research results, such as the aforementioned ICOPER project. These requirements tackle the usage of a learning outcome taxonomy that relates learners' intended LO and MOOCs.

Based on these initial requirements, we design and implement an application prototype to demonstrate the linkage of outcomes to MOOCs, and whether it is suitable to discover courses aligned to learners' intended LO. The application is developed using agile development technologies and methodologies (Highsmith & Cockburn 2001), which are very aligned to the principles of design-based research. The developed application is deployed to a production environment and used by real users for several months. The interactions of end-users with the application support a preliminary evaluation to refine the application in future iterations.

Problem statement and initial hypothesis

The problem addressed in this work can be summarized as enabling the discovery of MOOCs based on learning outcomes. As stated by Crespo et al. (2010), focusing on intended LO is part of a change of paradigm towards placing learners' needs in the center of the educational process. This emphasis on the learner rather than on closed curriculums is illustrated by the idea of MOOCs, which promote the freedom for learners to choose courses that satisfy their goals.

Our hypothesis is that by associating MOOCs with a taxonomy of learning outcomes, it will be possible to determine the suitability of each MOOC for each learner, and provide them with a list of courses that will most likely help him/her achieve the intended LO. One approach to do this is to use taxonomies for identifying gaps in learning skills and knowledge (Paquette 2007). Moreover, using taxonomies is a common practice in adaptive educational systems, as stated by Brusilovsky & Millán (2007) with the use of the term goal catalogs.

The results of a survey conducted by the authors during November and December 2012 show that there is a lack of awareness about the available MOOC platforms, hindering people from finding an appropriate course for their needs. 70 people based in Spain filled out this survey, 67% males and 33% females, 74% were in the age range of 25 to 40 years, and 87% had a higher education degree. The results indicate that 56% of the participants did not know MOOC platforms such as Coursera, edX, or Udacity. The difficulty of keeping up to date about available MOOCs increases even more for platforms of recent creation or intended for a more localized audience. Examples of the former are NovoEd, FutureLearn or iversity; MiríadaX and UNED COMA are examples of the latter, since they are intended for the Spanish-speaking audience. Moreover, people with a lower educational background are more likely to present a lower level of awareness about MOOC offerings.

Selecting MOOCs to help learners achieve their intended LO is a process similar to those that filter or recommend learning resources. In the technology enhanced learning field, a lot of research has been done in recommenders' systems for adaptive learning (see Manouselis et al. (2011) for a review of the main approaches implementing adaptive educational systems). This previous work refers to intended LO as learning goals or learning objectives as one of the features that conditions the behavior of an adaptive educational system (Brusilovsky & Millán 2007). Other several proposals include learning goals as part of the context in which learning objects are recommended (Verbert et al. 2012). According to this last idea and to the model proposed by Draschler et al. (2008), in this work we abstract MOOCs as learning objects employed in lifelong learning scenarios that can fit with the particular needs of an informal learner.

Therefore, the main research question behind this work is: how to facilitate the outcome-based discovery of MOOCs? To face this challenge, we assume using learning outcome taxonomies a) to match MOOCs with LO; and b) to enable students to define their intended LO.

Requirement definition

To design and develop a software system that addresses the problem, we state a set of initial requirements for this software system. Table 1 summarizes these requirements, which cover both the discovery and filtering of MOOCs based on learning outcomes.

Table 1: Requirements of the system.

Identifier	Requirement
Req1	Identify the MOOC learning outcomes and map them with a LO taxonomy
Req2	Manage users' profiles based on their intended LO
Req3	Support the discovery of MOOCs based on users' profiles
Req4	Filter MOOCs based on users' profiles

The first requirement (Req1) is that MOOCs must be explicitly associated with the learning outcomes they provide after successful completion. Nowadays, most MOOCs describe their learning outcomes either in the textual description of the course or during the presentation video. In order to enable the identification of MOOCs according to learners' intended LO, these learning outcomes must follow an established taxonomy. Several approaches have been proposed to assign learning outcomes to learning resources. For instance, the Learning Object Metadata (LOM) standard allows the classification by educational objectives. Another example is the combination of Learning Outcome Definition (LOD) and Personal Achieved Learning Outcomes specifications, both defined by Najjar, et al. (2009) as a result of the ICOPER project.

The second requirement (Req2) is that the system must allow users to specify the learning outcomes they intend to obtain through MOOCs. To facilitate the configuration of users' profiles, learners must be able to select their intended LO from the same established taxonomy. This taxonomy must be appropriate for the learner's field of interest (e.g. learners in Computer Science must employ a taxonomy that includes only those learning outcomes relevant for the Computer Science field). Furthermore, the system must allow users to indicate the MOOCs they have already completed and the learning outcomes they have already achieved. Thus, the user's profile must contain the information of intended and achieved LO plus the MOOCs already completed by the learner.

The third requirement (Req3) is that the system must allow the discovery of MOOCs based on intended LO. Users must be able to search for MOOCs, providing several filtering parameters. Examples of these parameters are keywords included in the name and description of the MOOC, workload demanded by the course, its duration and tools employed in the course (e.g., videos, forums and Q&A).

The fourth requirement (Req4) is that the system must provide personalized MOOCs filtering that match learners' intended LO. This functionality aims to allow users to find MOOCs in a more efficient way, helping them get a more efficient learning experience. The system must provide an open ranked list of MOOCs, that is, users must be able to access the entire MOOC catalogue but there must be an indicator of the suitability of each MOOC for the current user. Using this open ranked list allows users to access MOOCs that are outside their main domain of knowledge but that may be of interest for personal development.

A first implementation: moocrank

A preliminary implementation of moocrank (http://www.moocrank.com) was developed to validate the above-mentioned requirements. moocrank offers three important functionalities for learners. Firstly, the learner is able to look for MOOCs in many platforms within moocrank, indicating different filtering parameters. Secondly, the learner can select the learning outcomes s/he is willing to achieve, and receive a ranked list of MOOCs related to the intended LO. Finally, the learner can contribute to the community, annotating the courses s/he has completed as well as the achieved LO. For the design and implementation of moocrank, we took as input the requirements discussed in the previous section. According to the overall methodology, this prototype was implemented using rapid-prototyping technologies.

Selecting a learning outcome taxonomy

The first step towards the implementation of moocrank was to decide whether the system would be useful for any area of knowledge, or just for a specific field. For the first prototype, we decided to give support only to Computer Science, since this is the authors' field of expertise, and the adequacy of the learning outcomes taxonomy could be better validated. Besides, there are currently a lot of MOOCs on Computer Science in major MOOC platforms and they are the most popular ones. This fact allowed for generating a big enough initial MOOC database. To have a great number of courses in the system from the very beginning is convenient because it raises the possibilities of discovering and recommending MOOCs.

The next step was to find a taxonomy for describing the learning outcomes of the courses and the learners' intended LO. For that purpose we took as a reference the Computer Science Curricula 2013 (CSC2013), which describes the learning outcomes of Computer Science degrees. Moreover, CSC2013 is elaborated by well-recognized organizations such as ACM and IEEE-Computer Society (Sahami et al. 2013) and is usually taken as a reference in many universities for defining the curriculum of Computer Science degrees. The information provided by the CSC2013 is a set of learning outcomes organized in categories and subcategories. The main categories are called knowledge areas, and there are 18, ranging from "Algorithms and Complexity" to "Social Issues and Professional Practice".

Architecture

As MOOCs are inherent to the web, moocrank is being developed as a web application, and its architecture follows a client-server architecture (see Figure 1). moocrank implements the well-known Model-View-Controller (MVC) pattern. MVC enables the separation of models (data), views (used to render information in the client) and controller (to define the routes and processes that implement the expected behaviors).

At the model layer, a database stores the information of every entity involved in the system: MOOCs, learning outcomes, learners' profiles, and the matching between MOOCs and learning outcomes. MOOCs and learning outcomes are loaded into the system and cannot be modified by end-users.

On the client side, the system includes four views that play the role of interface for end-users. The first view allows users to register and sign into the system. There is a second view for users to indicate their intended LO, and a third view to indicate the MOOCs they have already taken along with the achieved LO. A last view presents a recommendation list with MOOCs sorted by their suitability to fulfill the user's intended LO.

Along with the web application, a set of other software components are being developed. Firstly, a set of scripts collects information about courses from the MOOC platforms and populate the courses database. Secondly, another script reads the CSC2013 information about learning outcomes and populates the outcomes database. Services that provide the functionality to manage learners' profiles, generate MOOC filtering, and allow users to annotate MOOCs and learning outcomes are also included in the architecture.

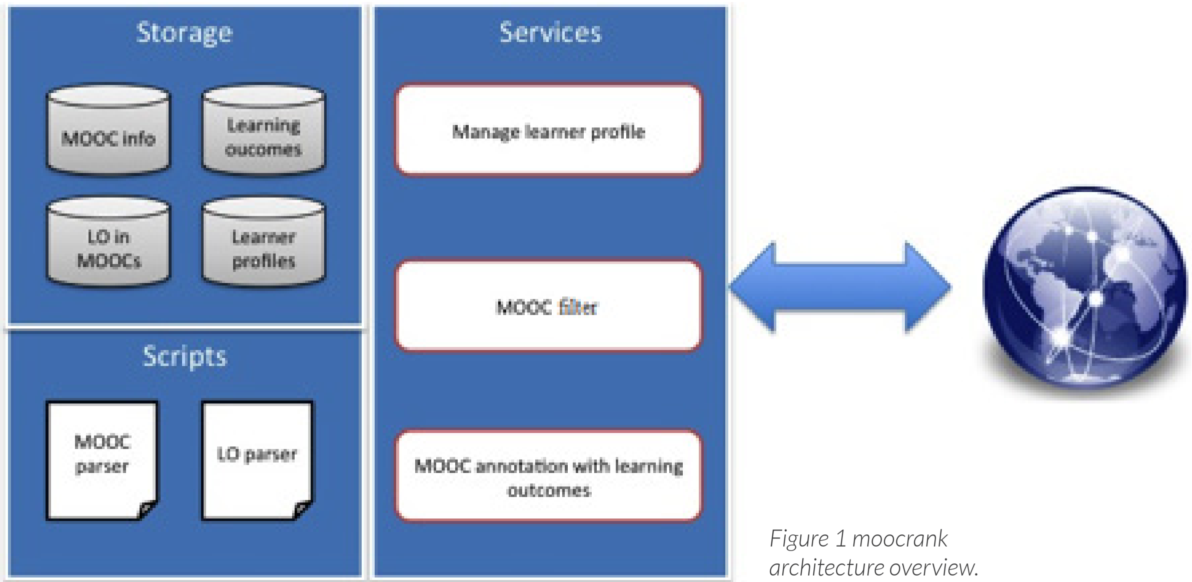

Figure 1 moocrank architecture overview.

Implementation

The next step in the implementation of moocrank was to collect the information necessary for the system to work. For that purpose, we found the CSC2013 in the InLOC (Integrating Learning Outcomes and Competences) digital format easy to read and load in our application database (http://wiki.teria.no/display/inloc/Information+-Model). The following step was to collect the information about MOOCs in our database, so that we could attach additional information to them about the learning outcomes that they allow students to achieve. For this first pilot, we collected the courses from the three most popular MOOC platforms: Coursera, edX and Udacity. Since each platform presents course information in a different format, they were analyzed separately. From all the courses collected, we selected only those belonging to the Computer Science field.

Because the courses collected did not provide enough information about learning outcomes, moocrank includes features to enable learners to annotate MOOCs with this information. Thus, when a learner finishes a course, s/he can indicate what learning outcomes were achieved. The information about learning outcomes associated to MOOCs is used by moocrank to further filter that course to other learners with similar intended LO. Therefore, we are making use of a crowdsourcing strategy to fill the existing gap between MOOCs and learning outcomes.

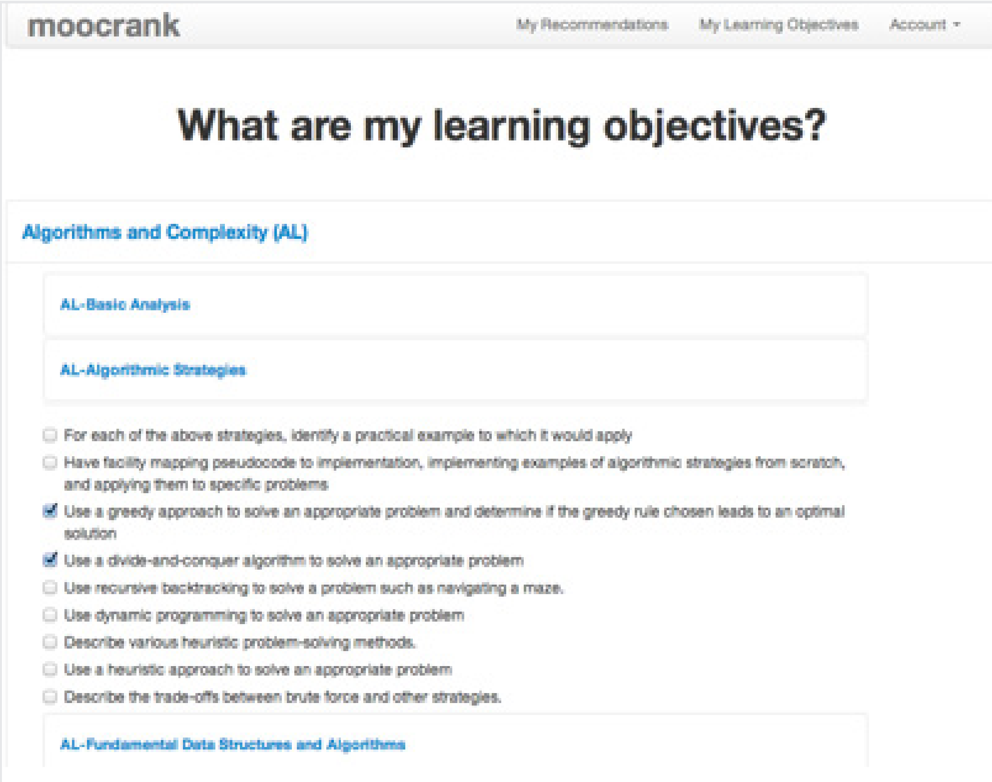

Figure 2 Screenshot of moocrank showing the selection of intended learning objectives in the users' profile.

Given the previous data sources (learning outcomes and courses), we developed a prototype of moocrank that implemented the functionality for discovering and recommending MOOCs based on learners' intended LO. For this development we made use of technologies that are commonly employed for quick digital prototyping such as bootstrap and jquery in the front-end, nodejs and express in the back-end and a mongodb database. For the deployment of the system, we have used the Amazon Elastic Compute Cloud (EC2), as well as github as the code repository.

The workflow that moocrank offers to end-users involves the following steps: The first time that the user accesses the application, s/he has to register in the system using email and password. Registration is required in order to store the students' profile information, necessary to present the MOOC recommendations. Once registered, the user is presented with the wishlist view, that is, the list of learning outcomes extracted from the CSC2013, ordered by category and subcategory. The learner should explore this list in order to find and indicate his/her intended learning objectives, that is, what outcomes s/he is willing to acquire (see Figure 2). After indicating his/her personal learning objectives, the user is presented with a set of filtered courses based on these objectives. The filtering approach is to display the courses ordered by their suitability for the user; the suitability is a simple count of the number of matches between the LOs intended by the learner and provided by the course. The user can explore the rank of courses and s/he can access more information about them, such as the platform in which the MOOC is deployed, the institution or teachers providing the content, and a direct link to join the course (see Figure 3). From the list of courses, the user can indicate that s/he has finished some of the courses. That action takes the user to the next screen, which contains a shortlist of learning outcomes that the course is likely to provide. Based on his/her experience during the course, the user selects from the shortlist of learning outcomes those that were actually achieved. moocrank makes use of this information for suggesting that course to other users. Hence, the accuracy of the filtering is improved as end-users evaluate the achieved learning outcomes of the MOOCs they have completed.

Discussion and next steps

In this paper, we presented the design and implementation of moocrank, a web application that recommends and enables the discovery of MOOCs aligned with learners' intended LO. The design of this application is based on a set of initial requirements that address the target research problem, and the results of research studies about outcome-based education.

As of this writing, other approaches are also centralizing the search of MOOCs deployed in different platforms. First, ClassCentral (http://www.class-central.com) aggregates MOOC information from several platforms, allowing a simple keyword-based search of courses. More attractive is the approach of CourseTalk (http://coursetalk.org) that enables learners to discuss and rate the courses they have followed. However, both approaches simply allow learners to search for courses, but without taking into account learners' intended outcomes, nor filtering the most suitable courses according to each student's profile.

Other initiatives promote replicating formal learning paths through MOOCs. For example, MyEducationPath (http://myeducationpath.com) allows users to define learning paths based on existing MOOCs. In this way, students pursuing learning objectives aligned to an existing learning path could use this path as a roadmap to enroll in MOOCs. The approach of SkillAcademy (http://skillacademy.com) is to facilitate the discovery of courses, although they are also composing tracks (learning paths) with courses from several sources that are closely related, covering similar fields or knowledge. For example, the Master for Business Administration (MBA) track includes courses from Udacity about startups and statistics, from edX about justice and some others from Coursera ranging from finance to marketing. These approaches that make use of learning paths mix courses from several sources, but they still lack the concept of learning outcomes, and how those courses are related to the learners' intended learning objectives.

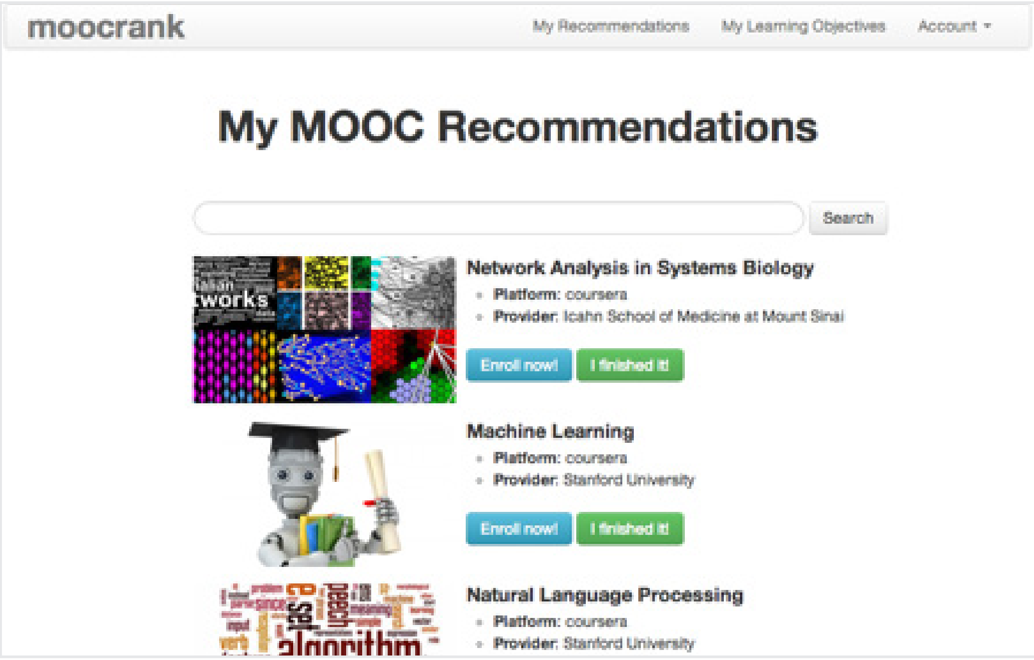

Figure 3 Screenshot of moocrank showing the outcome-based recommendation of MOOCs.

Moreover, moocrank could be easily applied in other contexts beyond Computer Science. The main concern for that application would be finding the appropriate learning outcome taxonomy for the domain. Given the taxonomy, it would be quite easy to include the courses from that area in the recommender and implement the annotation of courses with the chosen taxonomy. We envision moocrank to be able to support taxonomies in an extensible manner, which would allow the final taxonomy to be upgradable. Thus, users will be able to filter LOs based on the taxonomies that better fit their needs.

The MOOCs ranked list provided by moocrank is currently bound to MOOCs. But the same principles and procedures could be applied to other type of courses, online or not. The only thing that would change in moocrank would be the scripts collecting information about courses from the platforms. New scripts could be implemented to retrieve information from sources containing courses other than MOOCs. Furthermore, the processes of annotating learning outcomes and filtering courses could also be applied to more generic, open educational resources under the same procedure.

An important added value of moocrank is the crowdsourcing approach to annotate MOOCs and intended learning outcomes. As the number of moocrank users grows, the accuracy of the annotations will be much bigger. At that stage, moocrank will constitute a database of courses annotated by the community with the learning outcomes they achieved. This information from the community is expected to be more relevant for learners than the description about MOOCs provided by their teachers themselves.

moocrank has been implemented and deployed to a production environment, offered to any interested learners. Up to September 2013, moocrank received 312 visits with 191 unique visitors. The most common query is the word "software", and the most consulted courses are "Human Computer Interaction", "Software Defined Networking", "Startup Engineering" and "Cryptography", all of them provided by Coursera. Overall, the usage has not been as widespread as expected.

Given the previous results, the filtering mechanism was not as good as it should be, due to bootstrapping problems. That is, in order to do good filtering, moocrank needs information from users who previously completed the courses and indicated the achieved learning outcomes. Until a critical mass of courses is annotated, the ranked list is not very accurate. But, precisely due to the fact that the filtering is not too accurate for the first users, the system has not been used as widely as expected. That problem is known as the bootstrapping (or cold start) problem. In order to solve that situation, we are developing an automatic annotation tool. This tool annotates the courses with their intended learning outcomes based on existing information about MOOCs, like description, outline, background information, etc. The automatic annotation system makes use of a natural language processing algorithm in order to identify what outcomes are most likely provided by the course. Still, the automatic annotation tool can lead to mistakes. For that reason, learners will be able to amend the automatic annotations, and therefore the relationships between MOOCs and learning outcomes will evolve, driven by the moocrank users. In the case that users provide divergent annotations for the LOs of a course, the automatic annotations will serve as the judgment to decide the final LOs to be assigned. Once we get enough activity in the platform, we will be able to perform a better evaluation of its performance using typical metrics of information retrieval systems, such as precision and recall. On this line, one of the next steps is to thoroughly explore the literature in the recommenders' educational systems domain so as to incorporate a recommender module based on similarity measures already tested and evaluated in this field.

The next steps in the short term include leveraging moocrank with more social features to enable users to rank the courses, provide comments about their experience to help future participants, provide feedback about the teachers, the contents, the learning pace, etc. With that social information, learners will have more data to make more informed decisions about what course to take next.

Another future line is to improve the usability of the moocrank site, since we detected that the selection of learning outcomes by learners is a somewhat cumbersome task, due to large list of learning outcomes provided by CSC2013. Furthermore, we plan to update other components in the user interface like the recommendation screen, so that moocrank presents the courses ordered by relevance, although this information is not explicitly reported to the user.

Further plans also include collecting the dependencies between courses (what courses are pre-requisite for others) from the users themselves and other sources of information. With that information, we would be able to offer learning paths for the users to follow, aligned to the intended learning outcomes, and moocrank will not recommend advanced courses to novice learners.

Finally, the last future line we are going to explore is the application of moocrank for learning in the workplace. We think that the CSC2013 taxonomy could be used by employers to indicate the learning outcomes that a company wants for its employees. Following this idea, employees will be recommended which online courses to follow; courses that are also aligned with the training expectations of their employer. This could be useful to complement the training used in the workplace, by recommending courses aligned to company objectives. Furthermore, the application would aggregate the learning outcomes achieved during an employee's career, offering information on how the worker has updated their knowledge and skills to adapt to new company needs.

Acknowledgements

This work has been funded by the Spanish Ministry of Economy and Competitiveness Project TIN2011-28308-C03-01, the Regional Government of Madrid project S2009/TIC-1650, and the postdoctoral fellowship Alianza 4 Universidades. Prof. Carlos Delgado-Kloos wishes to acknowledge support from Fundación Caja Madrid to visit Harvard University and MIT in the academic year 2012/13. He also thanks numerous people from MIT, Harvard and edX for fruitful conversations carried out during this research stay.

References

Boyatt, R. & Sinclair, J. (2012). Navigating the Educational Cloud. Workshop on Learning Technology for Education in Cloud (LTEC'12). Advances in Intelligent Systems and Computing, 173, 179–191. Springer

Brusilovsky, P. & Millán, E. (2007). User models for adaptive hypermedia and adaptive educational systems. In The adaptive web, 3-53. Springer-Verlag.

Cooper, S. and Sahami, M. (2013). Reflections on Stanford's MOOCs, Communications of the ACM, 56, 2, 28-30.

Crespo, R.M., Najjar, J., Derntl, M., Leony, D., Neumann, S., Oberhuemer, P., Totschnig, M., Simon, B., Gutiérrez, I. & Delgado Kloos, C. (2010). Aligning assessment with learning outcomes in outcome-based education. Proceedings of the IEEE Engineering Education Conference (EDUCON 2010),

1239-1246. IEEE.

Draschler, H., Hummel, H.G. & Koper, R. (2008). Personal recommender systems for learners in lifelong learning networks: the requirements, techniques and model. International Journal of Learning Technology, 3, 4, 404-423.

Highsmith, J. & Cockburn, A. (2001). Agile software development: the business innovation. IEEE Computer Society, 34, 9, 120-127.

Kalz, M., Specht, M., Nadolski, R., Bastiaens, Y., Leirs, N. & Pawlowski, J. (2010). OpenScout: Competence based management education with community-improved open educational resources. Proceedings of the 17th EDINEB Conference: Crossing Borders in Education and work-based learning, 137-146. FEBA ERD Press.

Manouselis, N., Draschler, H., Vuorikari, R., Hummel, H. & Koper, R. (2011). Recommender Systems in Technology Enhanced Learning. In Recommender Systems Handbook, 387–415. Springer. Retrieved September 2013 from http://www.springerlink.com/index/10.1007/978-0-387-85820-3.

Najjar, J., Grant, S., Simon, B., Derntl, M., Klobučar, T., Crespo-García, R.M., Delgado-Kloos, C., Vu, A., Nguyen-Ngoc, A.V., Pawlowski, J., Hoel, T. & Oberhuemer, P. (2009). ISURE: Model for describing learning needs and learning opportunities taking context ontology modelling into account. Deliverable D2.2 from ICOPER. Retrieved September 2013 from http://www.icoper.org/results/deliverables/D2-2.

Pappano, L. (2012). The year of the MOOC. The New York Times, Retrieved September 2013 from: http://www.nytimes.com/2012/11/04/education/edlife/massive-open-online-courses-are-multiplying-at-a-rapid-pace.html.

Paquette, G. (2007). An ontology and a software framework for competency modeling and management. Educational Technology & Society, 10, 3, 1-21.

Sahami M., Roach, S., Danyluk, A., Fincher, S., Fisher, K., Grossman, D., Hawthorne, B., Katz, R., LeBlanc, R., Reed, D., Cuadros-Vargas, E., Dodge, R., France, R., Kumar, A., Robinson, B., Seker, R. & Thompson, A. (2013). Computer Science Curricula 2013 Ironman Draft (Version 1.0). The Joint Task Force on Computing Curricula Association for Computing Machinery IEEE-Computer Society, Retrieved September 2013 from: http://ai.stanford.edu/users/sahami/CS2013/ironman-draft/cs2013-ironman-v1.0.pdf.

Verbert, K., Manouselis, N., Ochoa, X., Wolpers, M., Draschler, H., Bosnic, I. & Duval, E. (2012). Context-Aware Recommender Systems for Learning: A Survey and Future Challenges. IEEE Transactions on Learning Technologies, 5, 4, 318–335.

Wang, F. & Hannafin, M.J. (2005). Design-based research and technology-enhanced learning environments. Educational Technology Research and Development, 53, 4, 5-23.