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ICIW 2020

Foreword

The Fifteenth International Conference on Internet and Web Applications and Services (ICIW 2020), held between September 27 – October 1st, 2020, continued a series of co-located events that covered the complementary aspects related to designing and deploying of applications based on IP&Web techniques and mechanisms.

Internet and Web-based technologies led to new frameworks, languages, mechanisms and protocols for Web applications design and development. Interaction between web-based applications and classical applications requires special interfaces and exposes various performance parameters.

Web Services and applications are supported by a myriad of platforms, technologies, and mechanisms for syntax (mostly XML-based) and semantics (Ontology, Semantic Web). Special Web Services based applications such as e-Commerce, e-Business, P2P, multimedia, and GRID enterprise-related, allow design flexibility and easy to develop new services. The challenges consist of service discovery, announcing, monitoring and management; on the other hand, trust, security, performance and scalability are desirable metrics under exploration when designing such applications.

Entertainment systems became one of the most business-oriented and challenging area of distributed real-time software applications' and special devices' industry. Developing entertainment systems and applications for a unique user or multiple users requires special platforms and network capabilities.

Particular traffic, QoS/SLA, reliability and high availability are some of the desired features of such systems. Real-time access raises problems of user identity, customized access, and navigation. Particular services such interactive television, car/train/flight games, music and system distribution, and sport entertainment led to ubiquitous systems. These systems use mobile, wearable devices, and wireless technologies.

Interactive game applications require particular methodologies, frameworks, platforms, tools and languages. State-of-the-art games today can embody the most sophisticated technology and the most fully developed applications of programming capabilities available in the public domain.

The impact on millions of users via the proliferation of peer-to-peer (P2P) file sharing networks such as eDonkey, Kazaa and Gnutella was rapidly increasing and seriously influencing business models (online services, cost control) and user behavior (download profile). An important fraction of the Internet traffic belongs to P2P applications.

P2P applications run in the background of user's PCs and enable individual users to act as downloaders, uploaders, file servers, etc. Designing and implementing P2P applications raise particular requirements. On the one hand, there are aspects of programming, data handling, and intensive computing applications; on the other hand, there are problems of special protocol features and networking, fault tolerance, quality of service, and application adaptability.

Additionally, P2P systems require special attention from the security point of view. Trust, reputation, copyrights, and intellectual property are also relevant for P2P applications.
On-line communications frameworks and mechanisms allow distribute the workload, share business process, and handle complex partner profiles. This requires protocols supporting interactivity and real-time metrics.

Collaborative systems based on online communications support collaborative groups and are based on the theory and formalisms for group interactions. Group synergy in cooperative networks includes online gambling, gaming, and children groups, and at a larger scale, B2B and B2P cooperation.

Collaborative systems allow social networks to exist; within groups and between groups there are problems of privacy, identity, anonymity, trust, and confidentiality. Additionally, conflict, delegation, group selection, and communications costs in collaborative groups have to be monitored and managed. Building online social networks requires mechanism on popularity context, persuasion, as well as technologies, techniques, and platforms to support all these paradigms.

Also, the age of information and communication has revolutionized the way companies do business, especially in providing competitive and innovative services. Business processes not only integrates departments and subsidiaries of enterprises but also are extended across organizations and to interact with governments. On the other hand, wireless technologies and peer-to-peer networks enable ubiquitous access to services and information systems with scalability. This results in the removal of barriers of market expansion and new business opportunities as well as threats. In this new globalized and ubiquitous environment, it is of increasing importance to consider legal and social aspects in business activities and information systems that will provide some level of certainty. There is a broad spectrum of vertical domains where legal and social issues influence the design and development of information systems, such as web personalization and protection of users privacy in service provision, intellectual property rights protection when designing and implementing virtual works and multiplayer digital games, copyright protection in collaborative environments, automation of contracting and contract monitoring on the web, protection of privacy in location-based computing, etc.

We take here the opportunity to warmly thank all the members of the ICIW 2020 Technical Program Committee, as well as the numerous reviewers. The creation of such a broad and high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to ICIW 2020. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the ICIW 2020 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that ICIW 2020 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the field of Internet and Web applications and services.

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A Review On E-learning: Perspectives And Challenges

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***Abstract*—E-learning has been receiving increasing attention in recent years. Many educational organizations have implemented Technology Enhanced Learning Environments (TELE) to improve student learning performance. This paper presents an overview of e-learning area, with a goal of providing references to fundamental concepts and identifying challenges for the broad community of e-learning practitioners. Until now, pedagogical content has been considered as a critical issue. Thus, we discuss recent content personalization's studies and the most important approaches.**

Keywords-E-learning; Technology Enhanced Learning Environments (TELE); Massive Open Online Courses (MOOC); Dropout Problem; E-learning Content Evaluation.

I. INTRODUCTION

Distance education or distance learning has existed for centuries, before the advent of the Internet. The way of practicing has evolved with the development of technologies. In the beginning, mail was used to send homework and receive corrections. By 1921, courses were broadcast in the United States. From 1939, it was the turn of the telephone and television. Since 1990, distance learning has emerged in the United States and Canada with the development of the Internet. Today, we are using TELE that allow us to do everything we have done by correspondence.

This study gives a historical overview of the field of e-learning and provides details on the existing challenges, focusing on those regarding the dropout rate of learners.

In spite of the limits that exist, e-learning offers acceptable solutions. This paper is designed to inform practitioners, policy developers and other stakeholders about the necessity of e-learning, which is becoming an important factor for education as well as business [1][2]. We dedicate this paper to those who want to reflect more deeply upon the adaptive capacity of e-learning to technological mutations [3]. This paper can interest, also, those who want to gain a greater understanding about how e-learning is a promoting field of scientific research.

The aim of this study is to identify key concepts, studies and issues, to highlight the learning dropout phenomenon and make recommendations especially for data scientists to guide future research towards the improvement of pedagogical content. For the purpose of this review, electronic database like Google scholar, ScienceDirect and JSTOR were searched using keywords such as e-learning, e-learning definition, MOOC, learner dropout. Selection criteria included: articles published in English, articles focusing on e-learning, recent articles.

This paper is organized as follows. Section 1 begins by giving general panorama of the paper. In Section 2 we present the concept of e-learning, underline the content personalization issue and trace the advances in TELE. In Section 3, we highlight the Massive Open Online Course (MOOC) revolution and examine some taxonomies. In Section 4, we draw attention to the most interesting challenge: the dropout rate of learners in e-learning. In Section 5, we finish by a conclusion, in which we give foretaste of our future work.

II. E-LEARNING

E-learning or electronic learning, literally means learning on the internet. Sangra et al. [4] identified four definitions categories, where each category focus on a specific aspect of the neologism: technology, knowledge, communication and pedagogy. The first category, Technology-Driven Definitions, portrays e-learning as the use of technology such as the web and electronic media for learning. The second one, Delivery-System-Oriented Definitions, presents e-learning as a mean of accessing knowledge. However, in the third category, Communication-Oriented Definitions, e-learning is considered like a communication, interaction and collaborative tool. The last category, Educational-Paradigm-Oriented Definitions, introduce e-learning as a new way of learning. However, learning needs change very quickly and the concept and functions of e-learning must continuously be adapted to these needs [4]. Nowadays, most of the efforts are addressed to the smart e-learning. Personalization is one of the promising subjects [5] and can be considered as an essential aspect of e-learning. Figure 1 below summarizes the five principal aspects of e-learning: knowledge, pedagogy, technology, communication and personalization.

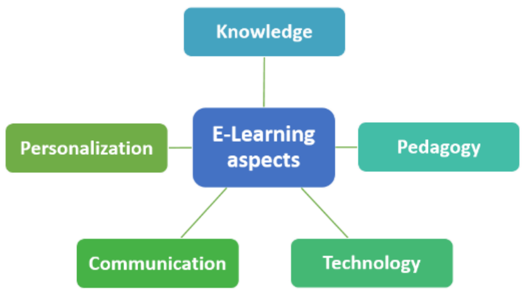

Figure 1. E-learning aspects.

As mentioned by Park et al. [6], "the students' performance can be improved through adaptive e-learning environments that suit their needs". Generally, there exist numerous methods, strategies and approaches to do that, namely personalized interfaces, personalized learning content, personalized learning paths, personalized diagnosis and suggestions, personalized recommendations, personalized prompts/feedback, and personalized professional learning guidance [7]. The challenge now is to give the most appropriate content to learners according to their interests and needs [8], and adapted to their profiles, abilities, preferences, characteristics, goals, talents, etc.

Chorfi and Jemni [9] have developed a personalized learning management system called PERSO. It is based on adaptation of the content to the learner's preferences and knowledge level. The latent semantic analysis was used to analyze learner's answer to a dynamic questionnaire to determine with a high accuracy the learner's knowledge level. Personalization have been also applied to new forms of learning delivery, such as the MOOC [10].

Based on the diversity of approaches, Esselmi et al. [11] provide generalized metrics to foresee the personalization strategies, which are the most appropriate to a specific course.

Sarwar et al. [12] tried to take advantages of web 3.0 and developed an adaptive e-learning framework, named Ontology based Adaptive, Semantic E-Learning Framework (OASEF). OASEF allows the delivering of learning contents that takes into account not only pedagogical requirements but it also considers learning activities as well.

An Educational Recommender System (ERS) exploring the use of argumentation based recommendation techniques as persuasive technologies was proposed by Heras et al. [13]. The purpose of the ERS is to show how arguments can be used as explanations to influence the behaviour of users towards the use of certain items. On the one hand, the ERS uses a database of Learning Objects (LOs), in which each LO included his metadata. On the other hand, the learner should register as a user in the ERS and fill out his educational information, such as his educational level or topics of interest. Then, he should answer a test to automatically determine his learning style. In this manner, the system can explore both characteristics of a student profile and LOs' metadata to recommend e-learning contents that meet the needs of the learner.

Employing ontology in education recommender systems interests many researchers. It is often considered as a useful tool for knowledge representation in ontology-based recommenders. Tarus et al. [14] explained that future works will focus more on hybridization of ontology-based recommendation with other advanced recommendation techniques to improve the recommendation's performance of the learning resources.

Personalized learning has become possible by implementing intelligent learning systems analyzing individual learning data. In this area, Belarbi et al. [15] propose a video recommender system across a Small Private Online Course (SPOC). They analyse firstly users' video behaviour while enrolling into a SPOC to estimate their interest in videos. Then, they try to find learners with similar profile using the unsupervised K-Means clustering algorithm and recommend target user the same videos, in which similar users are interested in.

Bourkoukou and El Bachari [16] propose an adaptive learning system-LearnFitII. As an automatic courseware authoring based on learning identification and collaborative filtering techniques, this system recognizes different patterns of learning style and learners' habits through testing the psychological model of learners and mining their server logs using K-Nearest Neighbors (KNN) and association rule mining algorithms.

Meunier [17] adopts an ontology-based approach to enriches an e-books and shows how it can be an adaptive and collaborative learning device.

After examining some interesting works, we can propose a new e-learning category definition in which e-learning is considered as a mean that provides personalized education. Thus e-learning can be defined as a new way of learning, using the technology to deliver a personalized training in a highly interactive environment.

A. Technology Enhanced Learning Environments (TELE) : Overview

In this Section, we focus on the major developments that have taken place in distance learning solutions from 1920 until now.

The first teaching experiences using computing as a pedagogy tool date back to the mid-1920s when Sidney L. Pressey designed several machines for the automatic testing of intelligence and information [18]. In the beginning, the device could only test and score. A student should press the right answer to move to the next question. If they are wrong the error is tallied. The last machine's generation could teach, but the behaviour of students had not been improved because examinations were corrected and returned after few hours or days.

In 1953, the psychologist Burrhus Frederic Skinner, inspired by Pavlov's work on conditioned reflexes, developed a method of teaching called programmed instruction. This method is based on the systematic progression of acquisitions by pre-structured and individualized programs. The fit between Skinner's behavioural theories and the technical possibilities revealed the concept of "Teaching Machine" in 1958 [19]. In front of a machine, the learner could follow a teaching by question/answer and learn by observing his own acts and the resulting consequences.

During the 1970s, the introduction of computer technology into programmed instruction gave birth to Computer-Assisted Education (CAE). CAE makes a dialogue between a learner and a computer possible. The dialogue is designed by teacher to help the learner achieve certain measurable goals in terms of knowledge and skills. CAE allows student the discretion of content, time, place, and pace of the training as it offers him the possibility to participate in simulations of situations and phenomena. Later, it may be noted that research on education and more generally on cognition, oriented computer applications on problems more directly related to learning than to teaching. Hence, “Computer-Assisted Education” (CAE) has been replaced by “Computer-Assisted Learning” (CAL) [20].

In the same period, the trend of learn by playing began to take its place in the world of distance education. The serious game was born [21]. It refers to games used for training, advertising, simulation, or education that are designed to run on personal computers or video game consoles [22]. The player experiences situations that are impossible in the real world for reasons of safety or cost for example to acquire knowledge and develop skills. So, as mentioned in Figure 2, a serious game is defined as an application with three components: experience, entertainment, and multimedia [23].

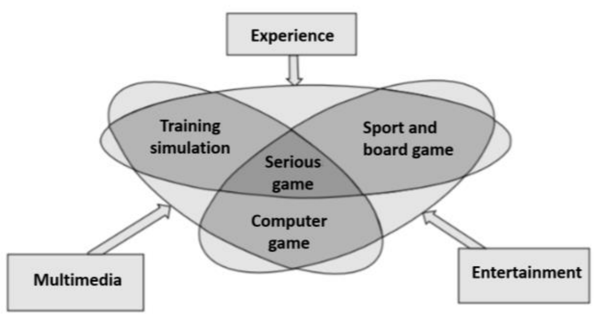

Figure 2. Definition of serious games [23].

By 1980s, CAL became in turn the ICAL Intelligent Computer-Assisted Learning. ICAL was appeared thanks to the contributions of artificial intelligence. Then, the intelligent tutors were born [24]. To perform his job successfully, an intelligent tutor has to be both pedagogue and expert in the domain to teach, he has also to know his students well and manage a real dialogue with them. Like this, learning has become more interactive and adapted to the learners.

At the turn of the 1990s, problem-solving systems were replaced by interactive problem-solving systems. We no longer talked about computer-assisted learning, but rather about learning through interactions with the teacher and other learners. These are the Interactive Learning Environments with Computer [25].

In the early 2000s, TELE emerged [26] to encourage, support and personalize learning. Today, a TELE refers to any computer environment designed to foster human learning, remotely at home or in-class at school, mobilizing human and artificial agents. A TELE can have multiple roles. It is not only used as an environment, which helps actors to realize educational activities, but it is also a presenting information tool, a communication tool and a support tool for teachers.

In TELE, courses can be distributed via a simple intranet, but can also be managed by specialized software called e-learning platform, learning management system or training management system.

There is a large number of e-learning platforms in the international market. Among the freely licensed platforms, we can mention, Claroline, Ganesha, and the open source solution Moodle, which took off in the 2000s to become an international reference. There also exist licensed proprietary platforms such as e-doceo, myTeacher, and Blackboard, which was born in the late 1990s. One of the most famous organizations in distance learning is the British Open University, which has been training hundreds of thousands of people around the world since the 1970s. MOOCs appeared in the late 2000s as the most popular TELE [27].

B. *Actors of Technology Enhanced Learning Environments (TELE)*

Many educational organizations have implemented e-learning platforms to improve student learning performance. TELE integrate tools for different e-learning actors. The objective is to facilitate their roles and functions. Figure 3 below is an adaptation of the general outline of distance learning platforms proposed by Sébastien [28]. It describes a model of a TELE.

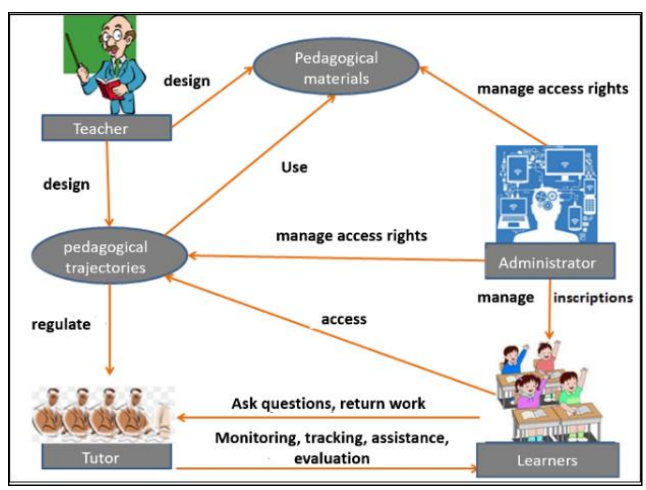

Figure 3. A TELE model.

A TELE involves essentially three main actors who are the learner, the tutor and the administrator.

The learner: consults and / or downloads the recommended educational resources, organizes his work, does exercises, self-evaluates and transmits questions and work to his tutor.

The tutor role can be subdivided into teacher-designer, teacher-trainer "tutor", teacher-corrector, etc. He/she creates pedagogical trajectories, follows up learners and provides them assistance.

The administrator: ensures the maintenance of the system, manage learners' registrations and the access rights as well to the platform as to the educational resources.

III. MASSIVE OPEN ONLINE COURSE: MOOC

MOOCs constitute a major evolution of the e-learning thanks to the increasing expertise in the use of open educational resources, among others. Since 2008, major universities all over the world offered MOOCs to promise the democratization of knowledge and lifelong learning. Anyone can access to online higher education courses anytime and anywhere. So how did MOOCs appear?

MOOCs were born from academic research on pedagogical methods, more specifically from an experiment conducted by two professors George Siemens and Stephen Downes from the University of Manitoba, Canada in august 2008 [29]. They published an online course about techniques of learning in a group entitled "Connectivism and Connective Knowledge" (CCK08) [30]. In few weeks, approximately 2,300 students signed for this course that was offered for free [31]. In the fall of 2011, the University of Stanford offers a massive free online course and gave the certificate to students who succeeded the exam. These students were evaluated by their professors. In December 2011, the American Massachusetts Institute of Technology (MIT) launched MITx; a non-profit organization that would offer online courses called "Massive Open On-line Courses" on an open-source basis [32]. More than 1.7 million registrants were reached [33]. In fall 2012, edX, a non-profit start-up from Harvard and the MIT, had 370,000 students in its first official courses [33]. EdX was offering high quality courses from the best universities and institutions to learners around the world.

A. *Specificities of the Massive Open Online Courses*

MOOCs are a revolutionary trend of educational technology today. Those online interactive trainings open to all are usually given by university professors and researchers and are intended for a public of learners, who will be supervised and accompanied in their learning [34].

As the name suggests, MOOCs are open, they are accessible to anyone who has an Internet connection and a computer, tablet, or Personal Digital Assisted (PDA). The registration is generally free [35]. Some MOOCs remain permanently accessible. Others can only be accessible after a registration to be made before a deadline and then become inaccessible; this is the case of France digital university (France Université Numérique). One can follow courses directly on the site of the establishment that produces them like the sites of FUN, Sorbonne and Harvard. One can, also, follow courses on platforms dedicated to MOOCs, such as, UDACITY, COURSERA and OPENCLASSROOMS, or on specific MOOCs specialized on certain areas.

The massive dimension is the feature that distinguishes the most MOOCs from classic e-learning. A course can be followed by millions of learners. By the end of 2017, the MOOC platforms have offered 9,400 courses worldwide and attracted 81,000,000 online registered students [36]. However, nearly in classical schools and universities, some professors integrate MOOCs into educational programs. They believe that it is more rigorous academically to experiment with interactive course formats; videos, PowerPoint and PDF documents, notes and abstracts. Thus, from massive and open, the courses become small and private, we speak here about Small Private Online Courses (SPOC), the knowledge's window held and diffused by teachers [37].

Initially, MOOCs were intended for students, today the typical profile of a participant in a MOOC is the employee who seeks to develop new skills. If he achieves his activities and succeeds MOOC tests, he can enhance his experience thanks to a certificate. We called this variety of MOOCs, Corporate Open Online Courses (COOCs) or Corporate MOOCs [38]. Designed on the model of MOOCs, COOCs are training modules for two types of public: the employees of a company and its customers. They are increasingly used in large companies like Renault, Bouygues, SNCF or Pernod Ricard to train employees and retain customers. MOOCs benefit from active pedagogy and innovations of Web 2.0. They get the best of the recent uses of social media and the contributions of the renewed conception of learning that promotes the co-construction of knowledge by the students themselves. Thus, learning is no longer vertical from the expert to the learner but is horizontal because of the exchanges between learners and pedagogical team, all thanks to the social features of the MOOC platforms. Indeed, learners can interact with the tutor and are invited to do it between them in the context of forums.

B. *Typology of MOOCs*

Between the first MOOC of 2008 called CCK08 and the first course proposed by MIT (MITx) the approach is visibly different. We are talking about two categories of MOOCs; cMOOC and xMOOC. The cMOOC, or the connectivist MOOC, is inspiring from connectivism, the learning theory proposed by Siemens [29] that focuses on the contribution of new technologies in learning and more specifically on the interactions of networked human communities. The cMOOC adopts a participative approach where learning is based on dialogue, interaction, and exploration. The cMOOC brings together a community of people over the same period. Everyone carries out its own researches, exchanges and collaborates with its peers, shares, publishes its own conclusions, produces around a common interest area and not around a precise subject. In this MOOC category, we talk about learning from others. The pedagogical content is partly co-built during the training.

Although, the role of the tutor is limited to a constant animation of the cMOOC to maintain the interest of learners. It involves facilitating interactions and identifying existing educational resources more than designing them. Thus, in the cMOOC the tutor is rather facilitator than instructor.

Known by transmissive MOOC, xMOOC tends to reproduce a traditional situation of teaching where the evaluation touches above the knowledge and not the skills. It adopts the transmission pedagogical model however it is organized with an attractive format using mainly pre-recorded video lectures and quizzes with no emphasis in networking. The content is predefined by the pedagogical team. Learning happens through the transmission of knowledge; the tutor is the expert, he distils its specific knowledge to learners who can communicate with him or ask questions and get answers on forums. xMOOC stands for eXtended MOOC. The term was coined in 2012 by Stephen Downes that says "It should be clear here that the xMOOC sense is not of eXtended MOOC but rather MOOC as eXtension of something else" [39]. One of the features of xMOOCs is to use them as a pedagogical resource in cMOOCs, or more generally, in the case of self-learning where the learner will build his own course according to his needs and own learning goals. Hence a MOOC is not necessarily either a xMOOC or a cMOOC. It can be a hybrid MOOC [40]. Some researchers wrote about other possible taxonomies [31], Market/Open/Dewey Model, Lane's classification, Clark Taxonomy.

IV. Learning Dropout Phenomenon: Discussion

In the world of training, increasing the success rate of learners is a major challenge. Nowadays, education is becoming a learner-centered market where learners are perceived as consumers of services. Most educational institutions at different levels work to attract those consumers and meet their needs. However, especially with the advent of MOOCs, this form of open and free distance training, the success rate remains tiny compared to the number of registrants. It usually runs around 10%. For example, of the 841,687 students enrolled at Harvard and the MIT, 5% earned such a certificate [41]. Is it really an alarming number? Can the certification rate be considered as an adequate performance metric for evaluating trainings in general or a TELE particularly? What knowledge and skills assessment techniques are most appropriate? Is it really the right place to talk about learner success or failure in a TELE? Several questions arise.

After studying uncertified learners' categories, we can say that problems related to success take mainly the form of dropping out of the online course, a phenomenon that has received a great deal of attention in e-learning [42][43][44][45]. School dropout, the term used for high school, college and university, is defined as the temporary or definitive studies interruption before obtaining recognition of prior learning, as a diploma or a certificate from an institution confirming the end of studies. In e-learning, the dropout rate varies from one TELE to another; around 7% to 10% [46] of the large numbers of participants enrolling in MOOCs manage to finish the course by completing all parts [47]. Thus, among uncertified learners, those who achieve trainings are far from being the majority. The percentage is explicable because motivations to follow a course or a training are numerous and varied, ranging from curiosity for the general theme of a course, to the desire to acquire knowledge and skills without being engaged or adopting a steady pace of work. As an example, Powell [48] distinguishes between learners who drop out in the first month, and those who leave during the training. He separates, also, between intrinsically motivated dropouts where learners have chosen to spontaneously pursue an online course or training outside the academic or professional program of extrinsically motivated learners who are indirectly engaged by their institutions. He shows that the last ones are the most persevering. The right question, then, is why some users manage to achieve courses, and others not? Generally, the learner's decision to interrupt his training cannot be attributed to an only one factor, but rather to a set of interrelated factors. Hence, the question of abandonment causes is complex. Until this moment, there is no real consensus in researches that can clearly identify the retention factors in e-learning platforms. However, according to Dalipi et al. [49] both student-related factors and e-learning platform related factors lead to a high number of dropouts. Pierrakeas et al. [50] summarize student-related factors in 4 major categories: financial, professional, academic and family, and personal reasons. On the other hand, concerning e-learning platform related factors, we found a need to distinguish between; problems, which can meet a learner in connection with the platform tools or services, and problems relevant to the quality of pedagogical contents such as text, picture, video and quiz.

V. Conclusion

With the advent of modern technologies, e-learning has been used in several sectors with significant impact. In this paper, we reviewed studies on the area of e-learning. We presented various definitions and proposed a new one. We described how e-learning has evolved. We revealed challenges and perspectives. To summarize, e-learning continues to grow around the world. The major challenge is to offer the learning where, when a learner wants and with the appropriate manner he/she desires [51]. The goal is to achieve learners' satisfaction. A specific attention is given to the phenomenon of dropping out called also non-persistence or disengagement from trainings. Nowadays, students' withdrawal has become the focus of learners, tutors, and researchers. As a result, issues of the e-learning efficiency continue to be the subject of a large number of recent scientific publications. The challenge for future TELE is to collect data produced by Learning Management Systems (LMS) and use this information to predict problems and opportunities that may arise [52].

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Our future work will focus on the evaluation of pedagogical content. The main objective is to help course designers in the educational reengineering. First, we will observe learners' behaviour throw their interaction traces in the TELE. Then, we will adopt machine learning approach to identify elements needing to be revisited in the content; the form, duration, presentation, etc. The aim is to detect courses content weaknesses in order to give course designers sufficient recommendations that could help to improve pedagogical content and undertake educational interventions.

REFERENCES

[1] N. Calvo and Ó. Villarreal, "Analysis of the growth of the e-learning industry through sustainable business model archetypes: A case study". Journal of Cleaner Production, 191, pp. 26-39, 2018.

[2] S. Singh and S. Z. Hussain, "Mechanising E-learning for equiping start-up entrepreneurs". Materials Today: Proceedings, 2020.

[3] S. Choudhury and S. Pattnaik, "Emerging themes in e-learning: A review from the stakeholders' perspective". Computers & Education, 144, 103657, 2020.

[4] A. Sangrà, D. Vlachopoulos, and N.Cabrera, "Building an inclusive definition of e-learning: An approach to the conceptual framework". The International Review of Research in Open and Distributed Learning, 13(2), pp. 145-159, 2012.

[5] M. Agrebi, M. Sendi, and M. Abed, M., "Deep Reinforcement Learning for Personalized Recommendation of Distance Learning". In World Conference on Information Systems and Technologies , pp. 597-606, 2019. Springer, Cham.

[6] O. C. Park and J. Lee, "Adaptive instructional systems," Educational Technology Research and Development, 25, pp. 651-684, 2003.

[7] H. Xie, H. C. Chu, G. J. Hwang, and C. C. Wang, "Trends and development in technology-enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2017," Computers & Education, 103599, 2019.

[8] M. K. Khribi, M. Jemni, and O. Nasraoui, "Toward a hybrid recommender system for e-learning personalization based on web usage mining techniques and information retrieval," In E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, pp. 6136-6145. Association for the Advancement of Computing in Education (AACE), October 2007.

[9] H. Chorfi and M. Jemni, "PERSO : Towards an adaptative e-learning system," Journal of Interactive Learning Research, 15(4), pp. 433-447, 2004.

[10] B. Jebali and R. Farhat, "Toward personalization in MOOCs," In the 6th International Conference on ICT & Accessibility proceedings, pp. 145-151, 2017.

[11] F. Esselmi, L. Jemni Ben Ayed, M. Jemni, and S. Graf, "Generalized metrics for the analysis of E-learning personalization strategies," Computers in Human Behavior, 48, pp. 310-322, 2015 .

[12] S. Sarwar, Z. U. Qayyum, M. Safyan, and R. F. Munir, "Ontology based adaptive, semantic e-learning framework (OASEF)," In Information Science and Applications (ICISA) pp. 1199-1212, 2016, Springer, Singapore.

[13] S. Heras, P. Rodríguez, J. Palanca, N. Duque, and V. Julián, "Using Argumentation to Persuade Students in an Educational Recommender System," In International Conference on Persuasive Technology, pp. 227-239, 2017. Springer, Cham.

[14] J. K. Tarus, Z. Niu, and G. Mustafa, "Knowledge-based recommendation: a review of ontology-based recommender systems for e-learning," Artificial intelligence review, 50(1), pp. 21-48, 2018.

[15] N. Belarbi, N. Chafiq, M. Talbi, A. Namir, and H. Benlahmar, "A Recommender System for Videos Suggestion in a SPOC: A Proposed Personalized Learning Method," In International Conference on Big Data and Smart Digital Environment, pp. 92-101, November 2018. Springer, Cham.

[16] O. Bourkoukou and E. El Bachari, "Toward a Hybrid Recommender System for E-learning Personnalization Based on Data Mining Techniques," JOIV: International Journal on Informatics Visualization, 2(4), pp. 271-278, 2018.

[17] J. M. Meunier, "Valorisation of a Pedagogical Digital Archive: The Example of an Ebook Enriched From An Ontology," In Proceedings of the 1st International Conference on Digital Tools & Uses Congress , p. 17, October 2018. ACM.

[18] B. F. Skinner, "Teaching machines," Science, 128(3330), pp. 969-977, 1958.

[19] R. M. Gagne, "Instructional technology: foundations," Routledge, 2013.

[20] T. E. Piemme, "Computer-assisted learning and evaluation in medicine," Jama, 260(3), pp. 367-372, 1988.

[21] M. Zyda, "From visual simulation to virtual reality to games," Computer, 38(9), pp. 25-32, 2005.

[22] T. Susi, M. Johannesson, and P. Backlund, "Serious games: An overview," , 2007.

[23] F. Laamarti, M. Eid, and A. E. Saddik "An overview of serious games," International Journal of Computer Games Technology, pp. 11-12, 2014.

[24] J. Self, "A perspective on intelligent computer-assisted learning," Journal of Computer Assisted Learning, 1(3), pp. 159-166, 1985.

[25] D. Guin and J. F. Nicaud, "Environnements interactifs d'apprentissage avec ordinateur," Quatrièmes journées EIAO de Cachan, École normale supérieure de Cachan, pp. 22-24 mars 1995, Eyrolles.

[26] N. Balacheff, "Les mots de la recherche sur les EIAH, enjeux et questions," STICEF review, 25(2), 2018.

[27] I.S. Vatskovskaya, "The Use of MOOCs for Professional Development of Translators," In Going Global through Social Sciences and Humanities: A Systems and ICT Perspective: Proceedings of the 2nd International Conference "Going Global through Social Sciences and Humanities", 27–28 February 2019, Tomsk, Russia pp. 255- 256. Springer.

[28] G. Sébastien, "Apprentissage collectif à distance, SPLACH: un environnement informatique support d'une pédagogie de projet," Doctoral dissertation, Université du Maine, 2001.

[29] G. Siemens, "Connectivism: A learning theory for the digital age,", 2008.

[30] A. Fini, "The technological dimension of a massive open online course: The case of the CCK08 course tools," The International Review of Research in Open and Distributed Learning, 10(5), 2009.

[31] S. Sanchez-Gordon, and S. Luján-Mora, "MOOCs gone wild," In Proceedings of the 8th International Technology, Education and Development Conference (INTED 2014), pp. 1449-1458, 2014.

[32] M.M. Waldrop, "Online learning: campus 2.0," Nature News, 495(7440), 160, 2013.

[33] W. Wang, L. Guo, L. He, and Y. J. Wu, "Effects of social-interactive engagement on the dropout ratio in online learning: insights from MOOC," Behaviour & Information Technology, 38(6), pp. 621-636, 2019.

[34] T. R. Liyanagunawardena, A. A. Adams, and S. A. Williams, “MOOCs: A systematic study of the published literature 2008-2012,” The International Review of Research in Open and Distributed Learning, 14(3), pp. 202-227, 2013.

[35] T. Clarke, “The advance of the MOOCs (massive open online courses) the impending globalisation of business education?,” Education+ Training, 55(4/5), pp. 403-413, 2013.

[36] D. Shah, “A Product at Every Price: A Review of MOOC Stats and Trends in 2017,” Retrieved August 28, 2018.

[37] A. M. Kaplan and M. Haenlein, “Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster,” Business Horizons, 59(4), pp. 441-450, 2016.

[38] K. Mori and L. Ractliffe, “Evaluating the use of a MOOC within higher education professional development training,” In Proceedings of the 25th International Conference Companion on World Wide Web, pp. 831-833. International World Wide Web Conferences Steering Committee, 2016.

[39] L. Robinson and D. Bawden, “International good practice in information literacy education,” Knjižnica: Revija za Področje Bibliotekarstva in Informacijske Znanosti, 62(1-2), pp. 169-185, 2018.

[40] F. J. García-Peñalvo, Á. Fidalgo-Blanco, and M. L. Sein-Echaluce, “An adaptive hybrid MOOC model: Disrupting the MOOC concept in higher education,” Telematics and Informatics, 35(4), pp. 1018-1030, 2018.

[41] L. Rai and D. Chunrao, “Influencing factors of success and failure in MOOC and general analysis of learner behavior,” International Journal of Information and Education Technology, 6(4), 262, 2016.

[42] C. Pierrakeas, G. Koutsonikos, A. D. Lipitakis, S. Kotsiantis, M. Xenos, and G. A. Gravvanis, “The Variability of the Reasons for Student Dropout in Distance Learning and the Prediction of Dropout-Prone Students,” In Machine Learning Paradigms, pp. 91-111, 2020, Springer, Cham.

[43] S. Goel, A. S. Sabitha, T. Choudhury, and I. S. Mehta, “Analytical Analysis of Learners’ Dropout Rate with Data Mining Techniques,” In Emerging Trends in Expert Applications and Security, pp. 583-592, 2019, Springer, Singapore.

[44] O. S. Da Costa and L. B. Gouveia, “Dropout in distance learning: a reference model for an integrated alert system,” In Proceedings of the Euro American Conference on Telematics and Information Systems, pp. 27-28, 2018, ACM.

[45] C. Burgos, M. L. Campanario, D. de la Pena, J. A. Lara, D. Lizcano, and M. A. Martínez, “Data mining for modeling students’ performance: A tutoring action plan to prevent academic dropout,” Computers & Electrical Engineering, 66, pp. 541-556, 2018.

[46] P. Gregori, V. Martínez, and J. J. Moyano-Fernández, “Basic actions to reduce dropout rates in distance learning,” Evaluation and program planning, 66, pp. 48-52, 2018.

[47] S. I. De Freitas, J. Morgan, and D. Gibson, “Will MOOCs transform learning and teaching in higher education? Engagement and course retention in online learning provision,” British Journal of Educational Technology, 46(3), pp. 455-471, 2015.

[48] R. Powell, “Openness and dropout: A study of four open distance education universities,” In M-2009: 23rd International Council on Distance Education World Conference on Open Learning and Distance Education, 2009.

[49] F. Dalipi, A. S. Imran, and Z. Kastrati, “MOOC dropout prediction using machine learning techniques: Review and research challenges,” In 2018 IEEE Global Engineering Education Conference (EDUCON) , pp. 1007-1014, April 2018, IEEE

[50] C. Pierrakeas, G. Koutsonikos, A. D. Lipitakis, S. Kotsiantis, M. Xenos, and G. A. Gravvanis, “The Variability of the Reasons for Student Dropout in Distance Learning and the Prediction of Dropout-Prone Students,” In Machine Learning Paradigms, pp. 91-111, 2020, Springer, Cham

[51] S. Ennouamani and Z. Mahani, “An overview of adaptive e-learning systems,” In 2017 eighth international conference on intelligent computing and information systems (ICICIS), pp. 342-347, December 2017, IEEE.

[52] D. Turnbull, R. Chugh, and J. Luck, “Learning Management Systems: An Overview,” Encyclopedia of Education and Information Technologies, 2019.

A Tool to Enable Knowledge Management

A case study at an educational institution

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***Abstract*—Federal Institute of Paraiba is a school maintained by the government. To enable its operation, it defines and adopts hundreds of organizational processes described by resolutions proposed and approved by its various superior boards. However, unfortunately, the reality is that many employees do not know how the institute works and see everything as complex and unnecessary bureaucracy. This leads to more work and delays due to petitions that are unclear and are missing information. To mitigate this problem, in this paper, we are proposing an app that will concentrate information, in a colloquial language, about petitions, such as regulation and mandatory attachments, as well as create a new communication channel by grouping, in a virtual community, employees from the same Campus. We presented our prototype to some course coordinators and directors and they agreed about the importance of the app to improve the current workflows from the institute and to educate the community.**

Keywords-knowledge management; federal institutes; universtity; application; social network.

I. Introduction

Knowledge Management (KM) is an effort to increase useful knowledge within the organization [1]. Usually, the sources of knowledge are skillful employees and/or the documented expertise that was produced over the years. Ways to achieve this include encouraging communication, offering opportunities to learn, and promoting the sharing of appropriate knowledge objects and/or artifacts [1]. To support KM policies, organizations can use information systems. These KM tools collect, store and share the intellectual capital that the organization has. With the help of KM tools, organizations start to use their intellectual capital to optimize processes, develop innovative solutions, stimulate creativity and increase productivity.

In this paper, we present our proposal to mitigate some KM problems that we observed in Federal Institute of Paraiba (IFPB) (a Brazilian public educational institution): a multi-platform app that promotes the KM in educational institutions, regarding the internal rules to start any type of petition. We observed that many employees of the IFPB are unaware of the institution's regulations, even due to the inherent complexity of these regulations, which often causes difficulties and even errors when structuring a petition. Our solution helps in maintaining the knowledge in a unique place, where employees will be able to educate themselves on how to proceed to start a petition and through which departments the petition will go. This will also help course coordinators and directors, as it will reduce rework resulting from returning petitions with problems. In addition, our proposal will facilitate communication among employees from the same campus. Finally, we presented our proposal to course coordinators and directors who gave us a positive feedback and suggestions on how to improve the app.

It is important to highlight that, although our project is being developed for IFPB, the scenario that has been described may be common to other Federal Institutes and also to any educational institution in other countries. For this reason, we believe that our solution can easily fit in other contexts, mainly due to the architecture that we adopted when planning it. The app was developed in *Flutter*, a framework created by Google for building natively compiled applications for mobile, web, and desktop from a single codebase. In addition, we build a web application that works as administration panel and facilitates creating data to our platform, as well as delivering to our app, using web services.

This paper is organized as follows: Section II details the context that motivated our research; Section III presents related work, as well the theories related to KM; Section IV describes the architecture and stack used to develop the app; Section V present our proposal, from the user point of view; Section VI reports the impressions that we gathered from presenting our prototype to four employees in management positions; finally, Section VII closes our article with conclusions and future work.

II. Context and Motivation

In Brazil, Federal Institutes are schools maintained by the Federal Government that work with a multi-campus structure that offer a variety of courses, ranging from high school to postgraduate courses, such as Specialization and doctoral courses. The main goal of these institutes is offering free and high quality professional education. However, they also develop Research projects and Extension projects with the community. Today, the federal education network has 38 institutes with 661 campus spread across the country, in all its states [2]. The Federal Institute of Paraiba (IFPB) is one of oldest units, with 112 years old, and, currently, it has 20 campuses [3].

All Federal Institutes follow the same Brazilian federal law (law number 11.892 from 2008), but each one creates their own internal statute to guide and to rule their operations [2]. It is not different with IFPB. To enable its operation, IFPB defines and adopts hundreds of organizational processes described by resolutions proposed and approved by its various superior boards. These processes are essential for the functioning of the organization and, more broadly, they need to be carried out in order for the Institution to exist and to guarantee the legality of the acts performed by all its employees.

The knowledge about how and what occurs during the flow of a process is essential, especially for those directly associated to the success achievement of the main goal of the institute: teachers, course coordinators, directors and even students. However, unfortunately, the reality is that many employees do not know how their institute works and see everything as complex and unnecessary bureaucracy. This happens for many reasons: (1) there is a high amount of regulations and some are written in juridical terms that make its comprehension difficult (and others present an inherent high complexity); (2) there are only a few employees with an in-depth knowledge of these statutes to instruct others; (3) the changes in who occupies management positions are recurrent. This scenario represents a serious KM problem that can lead to a series of bad consequences [4].

For instance, although a petition can begin and end in the same sector, most petitions actually move through many departments and require several people authorizations, before being granted. Due to this complexity, errors can occur when in the structuring of these petitions that can lead to delays or even make them unfeasible. Let us take as an example a petition for carrying out an excursion. If there is any missing document or the motivations are unsatisfying, a delay can cause the class and the teachers involved to lose the time window for which the visit was planned.

III. Related Work

Knowledge Management (KM) is the process of creating, sharing, using and managing the knowledge and information of an organization [4]. It refers to a multidisciplinary approach to achieve organizational objectives by making the best use of knowledge [5]. Among the advantages of applying KM policies, we can cite: improvement of internal process and better fluidity, more efficient decision-making process and better results, maximization of intellectual capital, possibility of identifying organizational problems (bureaucracy, slowness, and communication problems) [4][5].

Using KM the knowledge transforms itself and it is transmitted. It changes from tacit to explicit and vice-versa. A senior employee can write a textbook using his thoughts about his work. This book will be read by others employees which will develop their impressions about what he does. The thoughts from the senior are his tacit knowledge. The textbook is an explicit form of his tacit knowledge that can be easily absolved by other. The impression from who read the book is the tacit knowledge that they developed after reading. This is the knowledge cycle. To support this cycle, it is common ground to use software based systems. In this matter, we believe is worth to mention: Wiki, Bitrix24 and AnswerHub and Confluence.

Wiki is a website that allows collaborative editing of its content and structure by its users. There are quite a few web sites that can help to create a Wiki (although some require payment for the service), for instance, MediaWiki [6], SlimWiki [7] and Wikidot [8]. Bitrix24 [9] is a social enterprise platform. It is a united work space which handles the many aspects of daily operations and tasks and provides companies with a full range of team working and social networking means. AnswerHub is a KM and community application that offers tools to create and manage an online knowledge-based community. It is possible collect, organize, and share knowledge in a variety of ways including articles, ideas, and questions and answers.

Our proposal reunites some features from all these tools, while also include some new. Each campus administrator will have easy access to near colleagues, since the tool virtually reunites employees of the same campus. Thus, likewise Wiki, administrators will also be able to create and share articles with their subordinates. Likewise the Beatrix24, our solution will improve communication channels, since it also include phone push notifications that will help to inform everyone from the same Campus about meetings and other deadlines. Likewise the AnswerHub, users will also find a section with Frequently Asked Questions (FAQ), where they will be able to share their own doubts and administrators will choose if the question is worth to be permanently added to the FAQ of the petition guide or not. Our solution will offer robust channels to concentrate and distribute knowledge inside the Federal Institutes' structure. In addition, we aim to make it available for use of other organizations.

IV. Stack and Architecute

Our proposal was developed using *Java* with *Spring Framework* (an application framework and inversion of control container for the *Java* platform) [10]. In the client-side, we used two distinct technologies, one for the mobile platform (*Flutter*) and other for the web platform (*Angular*). *Flutter* is a free and open-source mobile UI framework created by Google to create, using one programming language and one codebase, apps for different platforms [11]. *Angular* is an application design framework and development platform for building mobile and desktop web applications [12]. The software administration will be performed by directors and course coordinators using the web interface (written using *Angular*). This will facilitate creating data to our platform. Other users will consume these data using our mobile app available in both Play Store and Apple Store (written using *Flutter*). Finally, for data storage, the relational database chosen for ensuring integrity and data management was *PostgreSQL* [13].

In addition, we chose the REST (Representational State Transfer) Architecture style to structure our proposal, due to simplicity, ease of maintenance, high scalability and reliability in the resistance to failure. REST is a software architectural style that defines the set of rules to be used for creating web services. A Restful system consists of a client-side who requests the resources and a server who delivers the resources.

In Figure 1, we present the architecture of our proposal as a whole, where the client makes HTTP requests to the server.

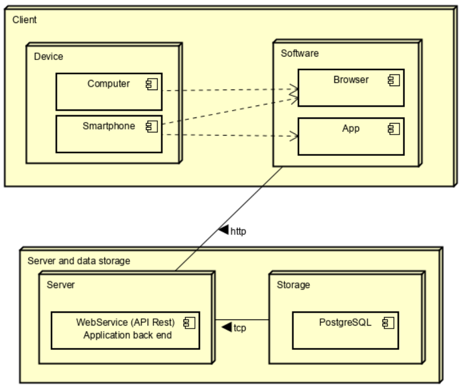

Figure 1. App architecture.

The user, on the client-side, though a browser or smartphone, accesses the system and makes requests for the API, in order to display the information about some petition. The server interprets the request, makes the necessary queries in the database and returns a response in JSON format to the client side. Finally, the app or browser displays the data contained in this JSON file to the client.

V. PRESENTING OUR PROPOSAL

The main goal of our proposal is help employees with structuring their petitions. Besides that, our app also creates a new communication channel that virtually reunites employees of Federal Institute from the same campus and it will facilitate notify all about meetings and other updates.

Regarding the petitions, users will have access to a list of commonest petitions that can be opened by teachers. To have access to these functions, users will have to register and login into the app. Figure 2 shows the Register page (on the left side) and the Login page (on the right side).

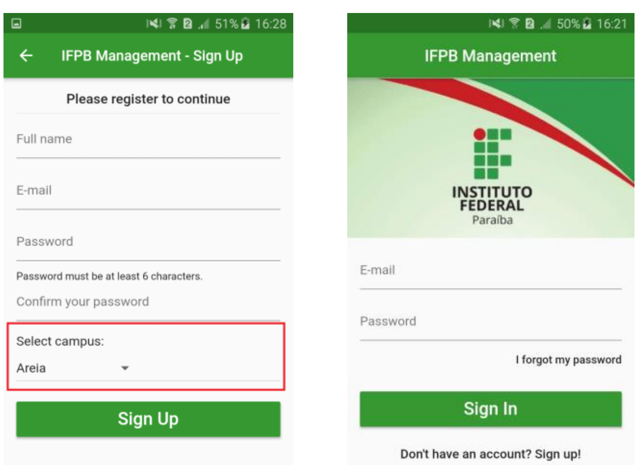

Figure 2. Register page (left) and Login page (right).

The system only allows users to register using their academic e-mail account. While registering, users will inform from which campus they are (the red box in the left side of Figure 2). This information is important to virtually reunite employees from the same campus in the same domain. The final version will enable the domain administrator do personalize primary color, icon and title. In this paper, we decide to describe the prototype using IFPB' design scheme. After being authenticated, users will visualize the list of petitions guides that directors previously saved through the web administration panel, as presented in Figure 3 (left). Since there is a chance of this list increases, they can filter using the text field on the top of the screen. They also have access to a sidebar-menu that serves for navigation only (right).

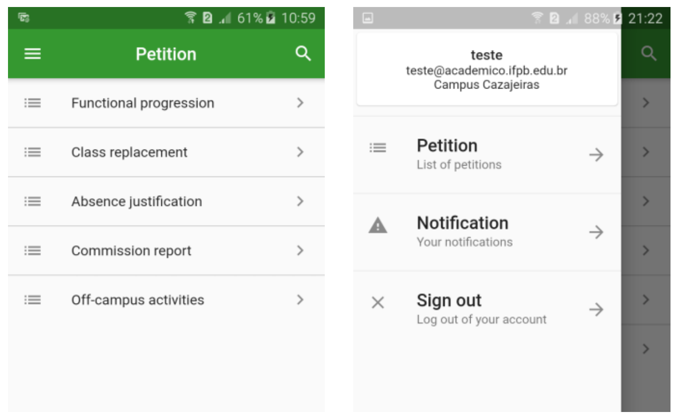

Figure 3. List of petitions guides (left) and Sidebar menu (right).

The Petition menu directs users for the List of petitions page. The Notification menu will direct users to the Notifications list, where they can see, for instance, meetings call and answers for their asked questions. After clicking in one of the petition guides, users are directed to the petition guide itself. Figure 4 shows the main elements that compose the guide.

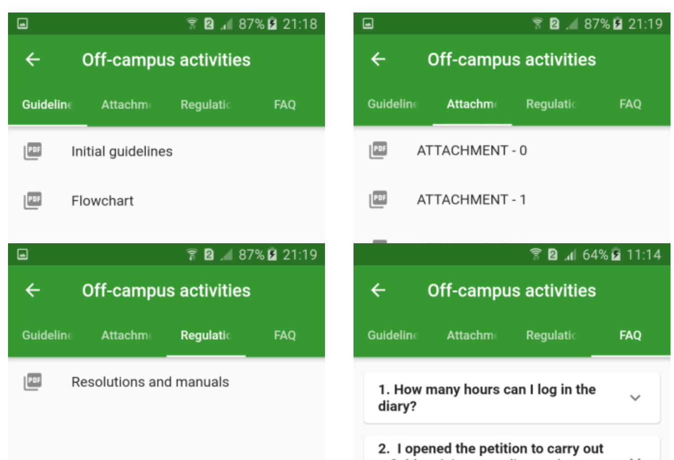

Figure 4. Guideline tab (top left), Attachments tab (top right), Related regulation tab (bottom left) and FAQ tab (bottom right).

Figure 4 shows the Guide page for opening a petition to request an off campus activities. Each petition guide is composed by four elements (four tabs): guideline, attachments, regulations and FAQ. The initial guidelines (top left) will be a document written with colloquial language that will detail the petition, present required attachment, link related regulation and help structuring the petition. This guide is written by directors or course coordinators, who know how the petition works, aiming to help their subordinates and even colleagues who come to occupy their position in the future. The initial guideline tab also will have an optional flowchart. The flowchart will be a visual guide that will describe the algorithm to correctly start the petition and through which departments the petition will go, before being finished. The attachment tab (top right) will group documents that must be included in the petition. The resolutions tab (bottom left) will group all the internal e external legislation related to the petition subject and mentioned in the guideline document. Finally, the FAQ tab will present questions previously elaborated by the author of the petition guide and also questions made by other employees and judged as worth to be public by the author of the petition guide. Users will be able to expand any number of questions from the FAQ to see the answer. In addition, they can send the own questions by clicking the "plus" button on the bottom right. The petition guide's author will receive and answer the employee; he will judge if he wants also to add the question and answer to the FAQ. We claim that gathering this information together will reduce the effort to learn about how to structure a petition and it will create a collective awareness on how organizational processes work.

VI. PRELIMINARY RESULTS

We presented our prototype to two directors and two course coordinators from four different campuses of IFPB. All of them have at least two years of experience in their respective positions. We demonstrated the app functions and explained how it could be used. Our main goal was to gather their opinions regarding our proposal, as well as to identify other functionalities that could be included in the beta version of the app. We asked them basic questions, such as "*which were the problems that they wish our app would solve?*" and "*what were their thoughts about the prototype?*". In this section, we report this preliminary feedback.

One of the course coordinators stated that our app would solve at least three problems: (1) the absence of required documentation in any petition; (2) forwarding petitions to departments without the endorsement of immediate supervisors; (3) the app can educate people about the legal basis for each type of petition and the time required for each request, which solves the problem of the employees' lack of knowledge of institutional rules and the deadlines involved in each type of petition.

Other respondents emphasized that the app would provide agility in the progress of petitions. "*In a daily basis, many petitions return to the interested party for presenting incomplete documentation or for not respecting the correct sequence between different departments of the Campus. Thus, the app can minimize these basic failures that slow the progress of petitions and can allow employees to consult information without the need to consult directors*", as stated by one of the respondents. "*Consistent guidance on how to handle a petition will avoid rework and delays, in processing*", as stated by other. He also said that these mistakes are not fault just of the employees, but the result of the complexity and amount of legislation usually involved.

Regarding the importance of our proposal, one of the respondents summarized the general thought: "*the first impressions are very positive because, with just one click, essential information will be available to the community in a summarized form*". Other coordinator suggested the integration between or app and the academic platform from IFPB (called SUAP): "*the proposal is very important for all employees of the institution, whether they are management position or not* [...] *In addition, if the app could be integrated with SUAP, it would further expand its potential for guidance in the elaboration of processes*".

Based on the received feedback, we believe that we are heading in the right direction. In addition, we were able to gather suggestions on how to improve our proposal, for the beta release.

VII. CONCLUSION AND FUTURE WORK

Knowledge Management (KM) is the process of creating, sharing, using and managing the knowledge and information of an organization. Improvement of internal process and better fluidity are some of the advantages of applying effective KM policies. However, in the context of IFPB, a Brazilian educational institution, we observed that many employees do not know how the institute works and see every petition as complex and unnecessary bureaucracy for asking for something. In addition, there are only a few employees with an in-depth knowledge of statutes associated to each type of petition available to instruct others colleagues. This scenario represents a serious KM problem that can lead to a series of bad consequences, such as rework, slowness, communication flaws and even failure to achieve organizational objectives.

To mitigate these problems, we proposed an app that will concentrate information about petitions in a colloquial language; as well it will create a new communication channel by grouping, in a virtual community, employees from the same Campus. We presented our prototype to some course coordinators and directors and they agreed about the importance of the app to improve the current workflows from the institute and to educate the community.

As future work, after finishing the app and releasing it to the IFPB's community, we aim to report the results achieved by the app use with in-deep employees and directors impressions. In addition, we are working in adding new features that will improve even more Knowledge Management, such as indexing data for easy recovering and the integration of our app with SUAP, the academic platform adopted by IFPB. Finally, we want to make a version of the app aiming newcomers students to educate them about the institute and how it works, as well about how to structuring their own types of petitions.

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REFERENCES

[1] C. McInerney, "Knowledge management and the dynamic nature of knowledge", Journal of the American Society for Information Science and Technology, vol. 53, pp. 1009–1018, C.R. 2002.

[2] Ministry of Education. *Federal Network of Professional, Scientific and Technological Education*. [Online]. Availbale from: http://portal.mec.gov.br/rede-federal-inicial/ [retrieved August, 2020]

[3] G. Rodrigues, "IFPB celebrates 110 years," Portal IFPB, 2019. [Online]. Availale from: https://www.ifpb.edu.br/noticias/2019/09/ifpb-comemora-110-anos [retrieved August, 2020]

[4] J. Girard and J. Girard, "Defining knowledge management: Toward an applied compendium", Online Journal of Applied Knowledge Management, vol. 3, 2015.

[5] A. Das, "Building Organizational Capabilities: an insightful examinatio of the principles and practices of making great organization", Ebooks2go Inc, 2017.

[6] https://www.mediawiki.org/wiki/MediaWiki [retrieved September, 2020]

[7] https://slimwiki.com/ [retrieved September, 2020]

[8] https://www.wikidot.com/ [retrieved September, 2020]

[9] https://www.bitrix24.com/ [retrieved September, 2020]

[10] https://spring.io/ [retrieved September, 2020]

[11] https://flutter.dev/ [retrieved September, 2020]

[12] https://angular.io/ [retrieved September, 2020]

[13] https://www.postgresql.org/ [retrieved September, 2020]

Improving DMF with Hybrid Loss Function and Applying CF-NADE to the MOOC Recommendation System

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***Abstract*—Nowadays, with the strong development of platforms like Coursera, Edx, etc., Massive Open Online Course (MOOC) is not too strange for most people. The number of online courses also increases day by day. One of the problems raised is how to recommend users to choose the appropriate course. To address the problem, we applied the Deep Matrix Factorization (DMF) model to build a user-item interaction matrix with explicit rating and zero implicit feedback. We then improved the loss function to yield more accurate results. In addition, we also used the Collaborative Filtering Neural Autoregressive Distribution Estimator (CF-NADE) model to MOOC Recommendation system. Our experiment shows that two proposed approaches achieve better results than the other methods.**

Keywords: MOOCs; Recommendation; CF-NADE; DMF.

I. INTRODUCTION

The recommendation system has gone through three decades of development across many fields, and today the most successful models are using deep learning because it provides high accuracy. In the Fourth Industrial Revolution, online learning became an indispensable need for learners who yearn for knowledge, so MOOC platforms, such as Coursera [36] Edx [37] Khan Academy [38] etc. contain thousands of courses and millions of learners. The rapid increase in the number of courses on MOOCs poses a problem of how to choose the right course for learners themselves.

According to our survey, there is not much current research on MOOCs recommendation. These lead to the complexity of assessing user knowledge. A good course recommendation system will help learners not have to spend time trying out courses or reading feedback from other learners to find a suitable course. If a learner has to take 5 to 6 pre-trial courses and read hundreds of feedbacks from other learners before finding a suitable course for themself, they will be discouraged from looking for more courses. Jdidou et al. [11][12] showed that the use of the course recommendation system will optimize learners' profitability. Yanhui et al. [13] showed that 87.3% of the respondents rated highly in the effectiveness of a course recommendation system. Course recommendation systems have also been developed to increase the completion rates of learners [13] [14].

Data from MOOCs is usually the course name, content, as well as learner information, etc. One person can study many different courses. From there, we can simulate in the form of knowledge graph in which users, courses, etc. will be the vertices of the graph and the edge will be a relationship such as learning, voting, etc. This graph will get bigger and more complex as more courses are created and the number of learners increases. Recommending a suitable course for a specific user will be complicated both in time and accuracy.

Because the data can be represented in the form of knowledge graphs, we conducted a survey of approaches in knowledge graph mining and combined them with collaborative filtering methods in the recommendation system. In the results, we chose two models, improved and evaluated them on the Travel-well dataset [24] which is the MOOC data in Learning Resource Exchange (LRE) portal in Europe. Specifically, we used the DMF model and [16] CF-NADE model [10]. The DMF model uses the Matrix Factorization and the Deep Structured Semantic to construct a user-item matrix with explicit ratings and non-preference implicit feedback. The loss function improved to achieve better results than conventional loss functions. The CF-NADE model is used to predict the probability of rating and use the rating to recommend items to users.

The remainder of this paper is structured as follows. Section II describes the related works used in the recommendation. Section III, we present the theoretical principle of CF-NADE and DMF model and our improvements. In section IV, we conduct experiments on the Travel-well dataset. Section V is the conclusion and our future works.

II. RELATED WORKS

In recent years, deep learning has been widely applied in many different fields. Applying deep learning into the recommendation system also brings many good results [15] Salakhutdinov et al. [17] proposed the Restricted Boltzmann Machine (RBM) model with only one hidden layer, which is

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the first deep learning model used in the recommendation system. Zheng et al. [10] proposed a CF-NADE model based on the Neural Autoregressive Distribution Estimator (NADE) model and Restricted Boltzmann Machine for Collaborative Filtering (RBM-CF) model [17], which showed better results than RBM-CF in Netflix and Movielens dataset. Sedhain et al. [19] proposed an AutoRec model based on an autoencoder network to fill the missing rating from the input layer. These above models only use rating explicit feedback, and do not solve the cold-start problem. Wang et al. [20] presented a new model called Collaborative Deep Learning (CDL) using hierarchical Bayesian and Stack Denoising Autoencoders (SDAE) to solve the sparsity problem of data. Wu et al. [22] proposed a Collaborative Denoising Autoencoder (CDAE) model improved from the Denoising AutoEncoder (DAE) model. Pan et al. [23] improved the CDAE model by using three small CDAE models combined to form a new model called Correlation Denoising Autoencoder (CoDAE). Elkahky et al. [18] proposed the Multi-View Deep Neural Network (MV-DNN) model by combining multiple Deep Structured Semantic Model (DSSM) models to take advantage of common information between different regions. Later, Xue et al. [16] proposed the DMF method by combining matrix factorization and DSSM model, while improving the loss function to achieve better effectiveness and having less running time.

In the MOOCs recommender system, there are many research works apply deep learning methods. Yang et al. [2] use matrix factorization and context information forum apply on MOOC Forum thread. Kardan et al. [25] use social network analysis and association rule mining for MOOC forums. Raghuveer et al. [5] propose a reinforcement learning model to generate learning context and analyze learner information. Mi et al. [26] use the context tree applied to an online sequential recommendation. Pardos [6] uses Recurrent Neural Networks to handle learner's time on each page for predicted courses. Jing et al. [1] construct a content-awareness framework using users' access information to represent learners' interests and behavior features. Zhang et al. [3] used a deep belief network for the first time in MOOC recommendation. Then, Zhang et al. [35] improved a better accurate recommendation model using learner's information features, course content features, and learner-course feature vectors as inputs. Zhang et al. [4] also improved the Deep Belief Network (DBN) model and analyzed learner's style features. Pardos et al. [7] propose a Multifactor2vec model to improve the semantics of token embedding. While effective, these methods need data that has a lot of information about courses and very high computation. In 2020, Troussas et al. [39] has proposed a recommendation system that performs a learning analysis of a given user to suggest relevant courses for that user. In addition, this system can also predict user behavior, meaning that it predicts courses that users continue to study in the future; the system has received very positive feedback. In terms of predicting the course, 62.5% of the participants thought that the system suggested exactly the courses they wanted to study and only 9.375% of the participants surveyed thought that the system was unsuccessful. Regarding the prediction of user behavior, 68.75% of participants thought that it was very accurate and only 6.25% thought that this system predicted incorrectly.

Among the above methods, we found that Xue et al.'s DMF model [16] and Zheng's CF-NADE model [10] are suitable for the MOOC recommendation system. Therefore, in the next section, we present the basic theoretical principles of these methods, and improvements to increase the accuracy of the system.

III. MOOC Recommendation System

Initially, user and course data will be stored as a matrix. To turn this space into an appropriate form for later problems, we often use methods in graph embeddings such as factorization approaches, random walk approaches, and deep approaches. Among them, the deep approaches are being used quite a lot. In section A, we use the matrix factorization using deep learning because of its effectiveness in our problem. Section B will cover the foundation of the CF-NADE model.

A. Deep Matrix Factorization Model

DMF is a technique that combines the Matrix Factorization technique (MF) and DSSM.

DSSM is proposed by Huang et al. [28] used in web search. DSSM uses a deep learning model to rank documents for a query. In the beginning, DSSM maps query and documents into lower semantic space with a multi-layer non-linear projection. Then, for ranking web search, cosine similarity between the query vector and a document vector is applied.

Given a set include M users: $\mathbf{U=\{u_1,u_2,\ldots,u_M\}}$, and a set include N items: $\mathbf{I=\{i_1,i_2,\ldots,i_N\}}$. $\mathbf{R} \in \mathbb{R}^{\mathbf{MxN}}$ is the rating interaction matrix with $\mathbf{R_{ij}}$ is the rating of user **i** for item **j**, **unk** is unknown rating. Equation (1) presents user-item interaction matrix.

$$Y_{ij}=\begin{cases} 0,\text{if } R_{ij}=\text{unk} \\ R_{ij}, \text{otherwise} \end{cases} \quad (1)$$

where **u** is user, **v** is item; **i**, **j** is index of **u**, **v**. **Y** is user-item interaction matrix, $\mathbf{Y^+}$ is observed interactions, $\mathbf{Y^-}$ is zero elements in **Y**, $\mathbf{Y^-_{sampled}}$ is a set of negative instances from **Y** (in part or in whole). Then $\mathbf{Y^- \cup Y_{sampled}}$ is a set of training interactions. Row **i** of matrix **Y** is $\mathbf{Y_{i*}}$, column **j** of the matrix is $\mathbf{Y_{*j}}$.

1) Deep matrix factorization model (DMF)

DMF is proposed by Xue et al. [16] and used in the recommender system. This model uses explicit rating and zero implicit feedback to predict items based on rated items that users. The DMF model has input is an interaction matrix, like DSSM, this matrix is split into two multi-layer perceptrons (MLPs). Then, the output of these MLPs is latent representations. Finally, for calculating the correlation between two latent representations, we use cosine similarity. Figure 1 illustrates DMF model.

Suppose the input is vector **x**, the output is vector **y**, $\mathbf{l_i}$ is i^{th} hidden layer, $\mathbf{W_i}$ is i^{th} weight matrix, $\mathbf{b_i}$ is i^{th} biased. From

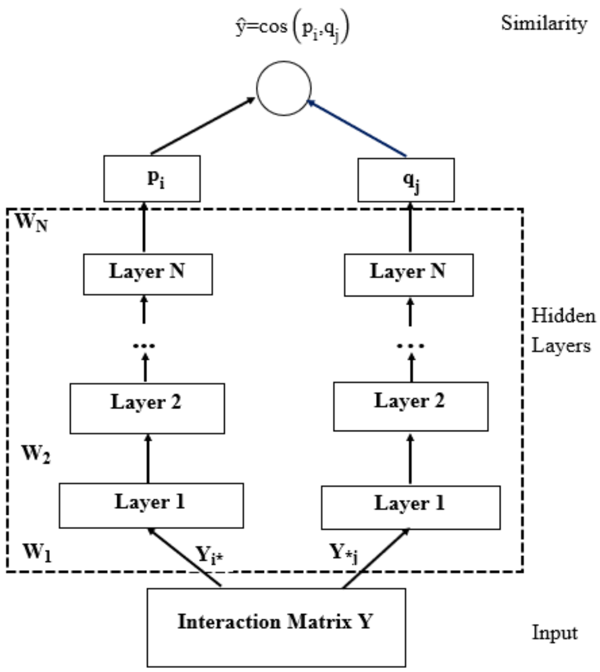

Figure 1. DMF architecture

interaction matrix **Y**, each user $\mathbf{u_i}$ is a vector of $\mathbf{Y_{i*}}$meaning i^{th} user rates for all items. Each item $\mathbf{v_j}$ is a vector $\mathbf{Y_{*j}}$, meaning j^{th} item rated by all users. MLPs use (2).

$$l_1=W_1x$$
$$l_i = f(W_{i-1}l_{i-1}+b_i), i=2,\dots N-1 \quad (2)$$
$$y = f(W_N l_{N-1}+b_N)$$

We use ReLU activation function in (3).

$$f(x)=\max(0,x) \quad (3)$$

In other words, this model has two MLPs, one for users and one for items, and outputs are mapped into low dimensional vectors in latent space in (4).

$$p_i= f_{\theta_N^U}\left(\dots f_{\theta_3^U}\left(W_{U2}f_{\theta_2^U}(Y_{i*}W_{U1})\right)\dots\right)$$

$$q_j= f_{\theta_N^I}\left(\dots f_{\theta_3^I}\left(W_{V2}f_{\theta_2^I}(Y_{*j}^T W_{V1})\right)\dots\right) \quad (4)$$

Then, we calculate the cosine similarity of two latent representations p_i and q_j with (5).

$$\hat{Y}_{ij} = F^{DMF}(\theta)=\text{cosine}\left(p_i,q_j\right)=\frac{p_i^T q_j}{\|p_i\|.\|q_j\|} \quad (5)$$

This is the first model that uses direct input as an interaction matrix and very useful in representing the final low dimension.

In the next section, we will represent an improved loss function, which increases the accuracy of the model.

2) Loss function

The general objective function in (6).

$$L=\sum_{u\in Y^+\cup Y^-} l(y,\hat{y})+\lambda\Omega(\theta) \quad (6)$$

where $\Omega(\theta)$ is regularizer and l(.) is loss function.

The loss function is an important part of the objective function. The better the loss function, the better the objective function. We optimize the objective function.

Some papers using Binary cross-entropy were proposed (7) [30]

$$L_{BCE} = -\sum_{(i,j)\in Y^+\cup Y^-} Y_{ij}\log\hat{Y}_{ij}+\left(1-Y_{ij}\right)\log\left(1-\hat{Y}_{ij}\right) \quad (7)$$

This function works effectively with implicit feedback because it addresses implicit feedback classification as binary classification.

Because we use both zero implicit feedback and explicit rating so that we use a new loss function that combines (7) and max rating. It is called Normalized cross-entropy loss in (8).

$$L_{NCE} = -\sum_{(i,j)\in Y^+\cup Y^-} \left(\frac{Y_{ij}}{\max(R)}\log\hat{Y}_{ij} + \left(1-\frac{Y_{ij}}{\max(R)}\right)\log\left(1-\hat{Y}_{ij}\right)\right) \quad (8)$$

where max(R) is max(Rating). In our data, we use max(R)=5 because 5 is the max rating.

Normalized cross-entropy can make Y_{ij} negative so that we use (9) to solve this problem.

$$\hat{Y}_{ij}^O = \max\left(\mu,\hat{Y}_{ij}\right) \quad (9)$$

where $\mu=10^{-6}$.

L2 loss function fits in solving the overfitting problem and is used in many papers [33] [32]. Equation (10).

$$L2 = \frac{\sum_i^m w_i^2}{2} \quad (10)$$

where $w_i^2=\sum_j^N w_{ij}^2$, and w_{ij} is the weight of the training instance (i,j); N is the dimension of w_{ij}.

We improve loss function by combining (8) and (10) and call it is Hybrid loss (11)

$$L_{Hybrid} = L_{NCE} + \alpha.L2 \quad (11)$$

This loss function that we improve not only fit rating data but it also avoids overfitting. When we use this loss function, we gain better results in experiments. In our experiment, we give $\alpha = 10^{-3}$. We represent the DMF with Hybrid loss function in Figure 2 (named Hybrid-DMF).

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Algorithm 1: Hybrid-DMF (Iter, neg-ratio, R)
Inputs:
Iter # The number of iterations
neg-ratio #negative ratio
R # Interaction matrix
Outputs:
W_{Ui}(i=1…N-1)# weight matrix for user
W_{Vi}(i=1…N-1)# weight matrix for item
1. **Initialize:**
   a. Initialize randomly W_U and W_V
   b. Y := Use (3)
   c. Y^+:= All non-zero interactions in Y;
   d. Y^- :=All zero interactions in Y;
   e. $Y^-_{sampled}$:= sample neg _ ratio* $||Y^+||$ (interactions from Y^-)
   f. T:=$Y^+ \cup Y^-_{sampled}$
2. **Loop it** from 1 to Iter:
   Loop each interaction of user **i** and item **j** in T:
   p_i, q_j := Use (4)
   $\hat{Y}^O_{ij}$:= Use (5) and (9)
   L := Use (11).
   End for
   End for

Figure 3. Hybrid-DMF algorithm

B. Collaborative Filtering Neural Autoregressive Distribution Estimator Model (CF-NADE)

Besides DMF, we found that the CF-NADE model is also suitable for the MOOC recommendation system.

Assuming there are M courses and N users, the user ratings are from 1 to K. We assume each user rated D courses and D≪M. With any user u, we will have the rating vector $\mathbf{r^u}=\left(r^u_{m_{o_1}}, r^u_{m_{o_2}},\ldots, r^u_{m_{o_D}}\right)$, where o is the permutation of (1, 2, …, D), $\mathbf{r^u_{m_{o_i}}} \in \{1,2,\ldots,K\}$ is present for the rating of user u and item $\mathbf{m_{o_i}}$. Section 2 will present the basic CF-NADE model.

1) Basic CF-NADE model

The CF-NADE model was proposed by Zheng et al. [10] developed from the NADE model, and can be used in the recommendation system. Basic CF-NADE has 3 layers (input layer, hidden layer, and output layer), and the basic CF-NADE can be extended to have one more hidden layer and become a deep neural network. Equation (13) shows the probability of the rating vector r. Where $\mathbf{r_{m_{o_{<i}}}}=\left(r_{m_{o_1}}, r_{m_{o_2}},\ldots,r_{m_{o_{i-1}}}\right)$ is the first i - 1 elements by index **o** of **r**.

$$p(r)=\prod_{i=1}^{D} p\left(r_{m_{o_i}} \middle| r_{m_{o_{<i}}}\right) \qquad (12)$$

Like NADE, CF-NADE models (12) with an autoencoder. Firstly, the CF-NADE model computes the hidden presentation in a hidden layer (13).

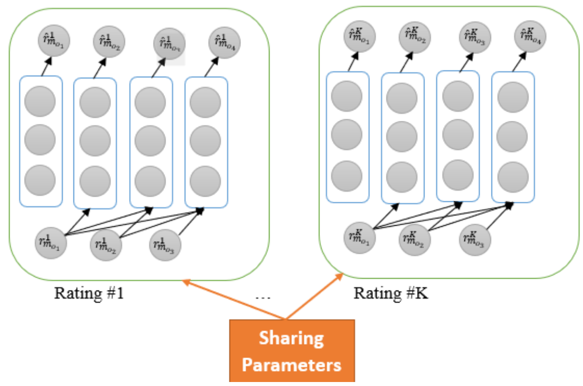

Figure 2. CF-NADE with sharing parameters

$$h\left(r_{m_{o_{<i}}}\right)=g\left(c+\sum_{j<i}\mathbf{W}^{r_{m_{o_j}}}_{:,\,m_{o_j}}\right) \qquad (13)$$

With g(.) is an activation function, such as tanh function. $\tanh(x) = \frac{\exp(x) - \exp(-x)}{\exp(x) + \exp(-x)}$, $W^k \in \mathbb{R}^{H\times M}$ is a connective matrix between input layer and hidden layer. We can rewrite (13) as (14).

$$p\left(r_{m_{o_i}}=k \middle| r_{m_{o_{<i}}}\right)=\frac{\exp\left(s^k_{m_{o_i}}\left(r_{m_{o_i}}\right)\right)}{\sum_{k'=1}^{K}\exp\left(s^{k'}_{m_{o_i}}\left(r_{m_{o_{<i}}}\right)\right)} \qquad (14)$$

where $\mathbf{s^k_{m_{o_i}}}\left(\mathbf{r_{m_{o_{<i}}}}\right)$ is the rating of course $\mathbf{m_{o_i}}$ by user **k** when knew the previous ratings $\mathbf{r_{m_{o_{<i}}}}$, has computed by (15)

$$s^k_{m_{o_i}}\left(r_{m_{o_{<i}}}\right)=b^k_{m_{o_i}}+V^k_{m_{o_j},:}h\left(r_{m_{o_{<i}}}\right) \qquad (15)$$

where V is connection matrix and b is bias with rating **k.**

2) CF-NADE model with sharing parameters.

Because if we use the basic CF-NADE model, we will have many models that depend on the number of users and rating range. Specifically, if we have **N** users and **K** ratings from 1 to K, we must use **N**x**K** basic CF-NADE model. Figure 3 shows how the CF-NADE model shared parameters. However, in reality, with each user, the number of items that user rates is very small, making the model difficult to optimize, so it is necessary to share parameters between the models, use only one model for N users and K ratings So that, (13) and (15) will change to (16) and (17) respectively.

$$h\left(r_{m_{o_{<i}}}\right)=g\left(c+\sum_{j<i}\sum_{k=1}^{r_{m_{o_j}}} W^k_{:,\,m_{o_j}}\right) \qquad (16)$$

$$s^k_{m_{o_i}}\left(r_{m_{o_{<i}}}\right)=\sum_{j\leq k}\left(b^j_{m_{o_i}}+V^j_{m_{o_i},:}h\left(r_{m_{o_{<i}}}\right)\right) \qquad (17)$$

where V^j, b^j is shared by k ratings.

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3) Training model with ratings' ordinal information.

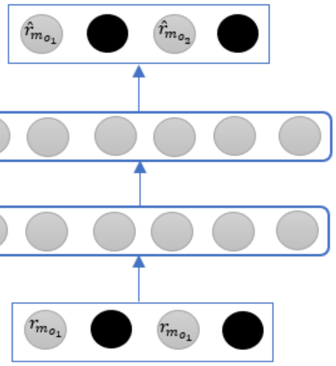

Figure 4. CF-NADE deep model

The model can be trained by minimizing the negative log-likelihood function (18).

$$-\log p(r) = -\sum_{i=1}^{D} \log p\left(r_{m_{o_i}} \middle| r_{m_{o_{<i}}}\right) \quad (18)$$

The current cost function treats different ratings as different labels. The labels with the highest probability will be the true label and not capture the ordinal information. Zheng et al. improved the cost function by adding label ordering information. When the realistic rating is k, this improvement makes the probability from 1 to k ascending and from k to K descending. So that it helps predicted ratings more accuracy. Assume that user rates k^{th}, then the rating from 1 to k has priority increase, and the value from k to K has priority decrease. Equation (19) is the improved function to compute the conditional probability of $r_{m_{o_i}} = k$, with given previous ratings $\mathbf{r}_{\mathbf{m}_{\mathbf{o}_{<i}}}$.

$$p\left(r_{m_{o_i}} = k \middle| r_{m_{o_{<i}}}\right) = \prod_{j=k}^{1} \frac{\exp\left(s_{m_{o_i}}^{j}\right)}{\sum_{t=1}^{j} \exp\left(s_{m_{o_i}}^{t}\right)} \prod_{j=k}^{K} \frac{\exp\left(s_{m_{o_i}}^{j}\right)}{\sum_{t=j}^{K} \exp\left(s_{m_{o_i}}^{t}\right)} \quad (19)$$

Cost function will be change to (20):

$$C_{hybrid} = (1-\lambda)C_{reg} + \lambda C_{ord} \quad (20)$$

where C_{ord} is an ordinal cost (19) and C_{reg} is a regular cost or negative log-likelihood (18) and λ is a hyper-parameter to determine the weight of C_{ord}.

4) Extend CF-NADE to a deep neural network.

According to Zheng et al., the CF-NADE model can have one additional hidden layer. Figure 4 describes CF-NADE when adding one hidden layer. When added a hidden layer to the model, computational complexity will increase, and the calculation formula of that layer is as (21).

$$h^{(l)}\left(r_{m_{o_{<i}}}\right) = g\left(c^{(l)} + W^{(l)} h^{(l-1)}\left(r_{m_{o_{<i}}}\right)\right) \quad (21)$$

where $l = 2, \ldots, L$ correspond to the hidden layers and the conditional probability $p\left(r_{m_{o_{<i}}}\right)$ is computed based on $h^{(L)}\left(r_{m_{o_{<i}}}\right)$. The computational complexity is $O(K\hat{D}H + H^2L)$. Where $\hat{\mathbf{D}}$ is the average of the number of courses that user rated, **H** is the nodes of the hidden layer. The Cost function is optimized using nonlinear optimization methods such as gradient descent.

Two suggested models above have effective results. Therefore, we will apply these models to the MOOC recommendation system. For comparison, in section IV, experience and results, we will evaluate two models with others to indicate the outperformance of two models compared to other methods.

IV. EXPERIENCE AND RESULTS

In this section, we will compare our improve models with other models with the MOOC dataset. Then, we show the results and comments.

A. Dataset

We use only the Travel-well dataset in [24] for our experiment because some other datasets are not fit for our model or not public. The Travel-well dataset was collected from the LRE portal includes 20 content providers. It contains information about the ratings and tagging behaviors of 98 learners in over six months (August 2008-February 2009), but there are only 75 learners rated for courses. In our experiment, we only use rating information.

TABLE I. TRAVEL-WELL DATASET

#learners (#users)	**#courses (#items)**	**#ratings**	**density**
75	1608	2156	0.0178

B. Parameter Settings

1) Parameter settings for Hybrid-DMF

We run the experiment with the following configurations: Python = 3.7.6, libraries such as Tensorflow-gpu = 1.5.0, numpy = 2.1.0.

Hyperparameter settings: learning rates = 10^{-4}, max epoch = 30 because our improved model converges less than 30 epochs, batch size = 256, early stopping = 5, the latent factor = 64 because with the number of latent factor < 64 we get wrong result and when the number of latent factor > 64, the result < when the number of latent factor = 64. The dimension of input user = 1024, and the item =512. The hyperparameters are tested from multiple hyperparameters and then choose the most optimal hyper-parameters.

2) Parameter settings for CF-NADE

The code runs with requirements: python 3.6.8. Dependence packages: Tensorflow (2.1.0), Tensorflow-gpu (2.1.0), Matplotlib, Keras (2.0.8), Pyspark (2.4.1).

Hyper-parameter settings: Learning rate = 10^{-3}, Hidden unit = 500, epochs = 20. The hyper-parameters are tested from multiple hyper-parameters and then choose the most optimal hyper-parameters. Specifically, the learning rate is chosen from 10^{-3}, $5*10^{-4}$ and 10^{-4}, epoch is chosen from 20 and 50, hidden units are 500 and 1000.

C. Metrics

To evaluate performance, we adopted the *leave-one-out* evaluation. We use two metrics: *Normalized Discounted Cumulative Gain* (NDCG) in [31] to evaluate the ranking performance of the relevance courses. NDCG is a metric, which assigns the results at top ranks, scoring successively lower ranks (22) and *Root mean square error* (RMSE) (23).

$$NDCG@K=Z_K \sum_{k=1}^{K} \frac{2^{r_i}-1}{\log_2(i+1)} \qquad (22)$$

where Z_K is the ideal ranking and has a value of 1; r_i is the graded relevance of item at position i. We use the simple binary relevance for our work: r_i=1 if the item is in the test set, and 0 otherwise.

$$RMSE=\sqrt{\frac{\sum_{i,j}^{M,N}(r_{ij}-\hat{r}_{ij})}{\#ratings}} \qquad (23)$$

For the NDCG metrics, larger values indicate better performance and RMSE, smaller values indicate better performance.

D. Results

To validate the effectiveness of 2 above models, we have selected five algorithms for evaluations (3 classical algorithms and 2 deep learning models): neighborhood-based collaborative filtering methods on item-based (IBCF) [34], neighborhood-based collaborative filtering methods on user-based (Pearson correlation) [34], single value decomposition (SVD) [9], Probabilistic Matrix Factorization (PMF) [8], AutoEncoder based on Collaborative Filtering (AutoRec) [19].

Because SVD, item-based CF and user-based CF are classical algorithms and do not use nonlinear optimization methods like neural networks. Therefore, we only compare RMSE of PMF, CF-NADE and Hybrid-DMF by epoch.

Table II shows RMSE on the test set between comparison methods. As we can see, two models we used have much better results than other methods. Hybrid-DMF has achieved the best RMSE (0.7916), and then CF-NADE (0.8283) for the second.

TABLE II. COMPARISON RMSE OF HYBRID-DMF, CF-NADE, AND OTHER MODELS ON TRAVEL-WELL DATASET

Models and Algorithms	RMSE
AutoRec	2.50037
IBCF	1.3366
UBCF	1.1016
SVD	0.9063
PMF	0.8651
CF-NADE	**0.8283**
Hybrid-DMF	**0.7916**

TABLE III. NDCG@K WITH DIFFERENT TOPKS

TopK	Hybrid-DMF	CF-NADE	AutoRec	SVD
1	0.3467	0.3554	0.0019	0.4927
5	0.3945	0.5505	0.0039	0.4875
10	0.4701	0.6606	0.0040	0.4833
20	0.5000	0.7694	0.0043	0.4800
30	0.5493	0.8225	0.0059	0.4789
50	0.5762	0.8665	0.0070	0.4770

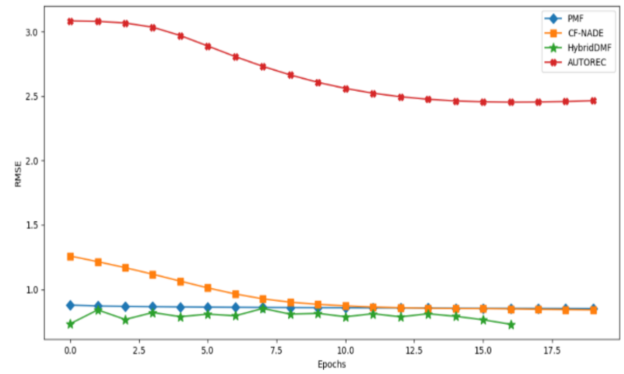

Figure 5. Comparison with RMSE of four models on Travel-Well dataset.

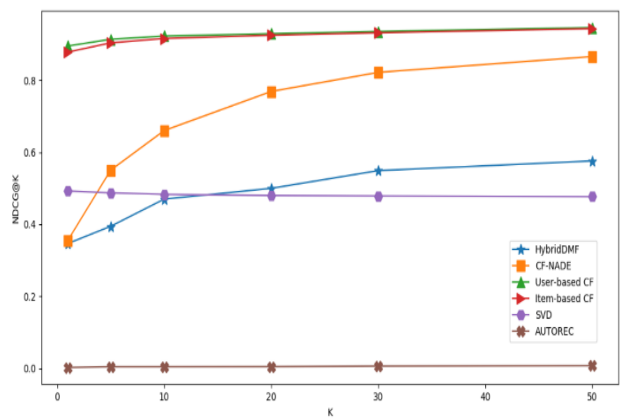

Figure 6. Comparison with NDCG@K on Travel-Well dataset.

Figure 5 shows the RMSE on the test set between PMF, CF-NADE and Hybrid-DMF, AutoRec by epoch. DMF has achieved the best RMSE. CF-NADE initially had a better RMSE than the PMF. However, later the CF-NADE has converged resulting in a better RMSE than the PMF. Finally, AutoRec has the highest RMSE error.

Figure 6 shows the NDCG@K metrics with K = {1, 5, 10, 20, 30, 50} of DMF, CF-NADE, UBCF, IBCF, AutoRec and SVD models. Table III is the detailed result with NDCG@K metric, respectively. In general, user-based CF and item-based CF algorithms have a better NDCG than deep learning algorithms but predict course rating is much worse than deep learning. One of the reasons for deep learning algorithms shown with NDCG measurements is not high is that data is not sufficient.

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V. CONCLUSION AND FUTURE WORKS

In this paper, we improved the DMF model with a new loss function (Hybrid-DMF) and combined with the CF-NADE model for the MOOC recommendation system. We evaluated the models on MOOC dataset in Europe. The results showed that the proposed approach is better than the other models with RMSE and NDCG@K measurements when evaluated on the Travel-well dataset. In the future, we will continue to improve DMF with some other loss functions. In addition, this model can be expanded from zero of implicit feedback to implicit feedback containing user feedback such as the click information. This model can also be improved by adding side information from users and items to get better accuracy. Improving CF-NADE can be done by implicit feedback information, such as user tagging for each course to improve the accuracy of the model.

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REFERENCES

[1] Jing, X. and Tang, J., 2017, August, "Guess you like: course recommendation in MOOCs," Proceedings of the International Conference on Web Intelligence (pp. 783-789).

[2] D. Yang, M. Piergallini and P. Rosé, "Forum Thread Recommendation for Massive Open Online Courses," Education Data Mining, 2014.

[3] Zhang, H., Yang, H., Huang, T. and Zhan, G., 2017, June, "DBNCF: Personalized courses recommendation system based on DBN in MOOC environment," 2017 International Symposium on Educational Technology (ISET) (pp. 106-108). IEEE.

[4] Zhang, H., et al, "A learning style classification approach based on deep belief network for large-scale online education," Journal of Cloud Computing 9 (2020): 1-17.

[5] R. Raghuveer, B. K. Tripathy, T. Singh and S. Khanna, "Reinforcement learning approach towards effective content recommendation in MOOC environments," 2014 IEEE International Conference on MOOC, Innovation and Technology in Education (MITE), Patiala, 2014, pp. 285-289, doi: 10.1109/MITE.2014.7020289.

[6] Pardos, Z.A., Fan, Z. and Jiang, W, "Connectionist recommendation in the wild: on the utility and scrutability of neural networks for personalized course guidance," User Model User-Adap Inter 29, pp. 487–525, 2019, doi:10.1007/s11257-019-09218-7.

[7] Pardos, Z.A. and Jiang, W., 2020, March, "Designing for serendipity in a university course recommendation system," Proceedings of the Tenth International Conference on Learning Analytics & Knowledge (pp. 350-359).

[8] Mnih, A. and Salakhutdinov, R.R., 2008, "Probabilistic matrix factorization," Advances in neural information processing systems (pp. 1257-1264).

[9] Zhang, S., et al, "Using singular value decomposition approximation for collaborative filtering," Seventh IEEE International Conference on E-Commerce Technology (CEC'05), IEEE, 2005.

[10] Zheng, Y., Tang, B., Ding, W. and Zhou, H., 2016, "A neural autoregressive approach to collaborative filtering," arXiv preprint arXiv:1605.09477.

[11] Jdidou, Y. and Khaldi, M., 2016, "Increasing the Profitability of Students in MOOCs using Recommendation System," International Journal of Knowledge Society Research (IJKSR), 7(4), pp.75-85.

[12] Jdidou, Y. and Khaldi, M., 2018, "Using Recommendation Systems in MOOC: An Innovation in Education That Increases the Profitability of Students," In Enhancing Knowledge Discovery and Innovation in the Digital Era (pp. 176-190), IGI Global.

[13] Yanhui, D., Dequan, W., Yongxin, Z. and Lin, L., 2015, November, "A group recommender system for online course study," 2015 7th International Conference on Information Technology in Medicine and Education (ITME) (pp. 318-320). IEEE.

[14] Labarthe, H., Bachelet, R., Bouchet, F. and Yacef, K., 2016, "Increasing MOOC completion rates through social interactions: a recommendation system," Research Track, p.471.

[15] Zhang, S., Yao, L., Sun, A. and Tay, Y., 2019, "Deep learning based recommender system: A survey and new perspectives," ACM Computing Surveys (CSUR), 52(1), pp.1-38.

[16] Xue, H.J., Dai, X., Zhang, J., Huang, S. and Chen, J., 2017, August, "Deep Matrix Factorization Models for Recommender Systems," In IJCAI (Vol. 17, pp. 3203-3209).

[17] Salakhutdinov, R., Mnih, A. and Hinton, G., 2007, June, "Restricted Boltzmann machines for collaborative filtering," Proceedings of the 24th international conference on Machine learning (pp. 791-798).

[18] Elkahky, A.M., Song, Y. and He, X., 2015, May, "A multi-view deep learning approach for cross domain user modeling in recommendation systems," In Proceedings of the 24th International Conference on World Wide Web (pp. 278-288).

[19] Sedhain, S., Menon, A.K., Sanner, S. and Xie, L., 2015, May, "Autorec: Autoencoders meet collaborative filtering," In Proceedings of the 24th international conference on World Wide Web (pp. 111-112).

[20] Wang, H., Wang, N. and Yeung, D.Y., 2015, August, "Collaborative deep learning for recommender systems," Proceedings of the 21th ACM SIGKDD international conference on knowledge discovery and data mining (pp. 1235-1244).

[21] Covington, P., Adams, J. and Sargin, E., 2016, September, "Deep neural networks for youtube recommendations," Proceedings of the 10th ACM conference on recommender systems (pp. 191-198).

[22] Wu, Y., DuBois, C., Zheng, A.X. and Ester, M., 2016, February, "Collaborative denoising auto-encoders for top-n recommender systems," Proceedings of the Ninth ACM International Conference on Web Search and Data Mining (pp. 153-162).

[23] Pan, Y., He, F. and Yu, H, "A correlative denoising autoencoder to model social influence for top-N recommender system," Frontiers of Computer Science volume 14, 2020.

[24] Verbert, K., et al, "Dataset-driven research for improving recommender systems for learning," Proceedings of the 1st International Conference on Learning Analytics and Knowledge. 2011.

[25] Kardan, A., Narimani, A. and Ataiefard, F., 2017, "A hybrid approach for thread recommendation in MOOC forums," International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 11(10), pp.2195-2201.

[26] Mi, F. and Faltings, B., 2016, July, "Adaptive Sequential Recommendation Using Context Trees," IJCAI (pp. 4018-4019).

[27] Deshpande, M. and Karypis, G., 2004, "Item-based top-n recommendation algorithms," ACM Transactions on Information Systems (TOIS), 22(1), pp.143-177.

[28] Huang, P. S., et al, "Learning deep structured semantic models for web search using clickthrough data," Proceedings of the 22nd ACM international conference on Information & Knowledge Management, 2013.

[29] He, X., Zhang, H., Kan, M.Y. and Chua, T.S., 2016, July, "Fast matrix factorization for online recommendation with implicit feedback," Proceedings of the 39th International ACM SIGIR conference on Research and Development in Information Retrieval (pp. 549-558).

[30] He, X., Liao, L., Zhang, H., Nie, L., Hu, X. and Chua, T.S., 2017, April, "Neural collaborative filtering," Proceedings of the 26th international conference on world wide web (pp. 173-182).

[31] He, X., Chen, T., Kan, M.Y. and Chen, X., 2015, October, "Trirank: Review-aware explainable recommendation by modeling aspects," Proceedings of the 24th ACM International on Conference on Information and Knowledge Management (pp. 1661-1670).

[32] Nie, F., Huang, H., Cai, X. and Ding, C.H., 2010, "Efficient and robust feature selection via joint ℓ2, 1-norms minimization," In Advances in neural information processing systems (pp. 1813-1821).

[33] Chang, K.W., Hsieh, C.J. and Lin, C.J., 2008, "Coordinate descent method for large-scale l2-loss linear support vector machines," Journal of Machine Learning Research, 9(Jul), pp.1369-1398.

[34] Aggarwal C.C., 2016, "Neighborhood-based collaborative filtering," Recommender systems (pp. 29-70). Springer, Cham.

[35] Zhang, H., Huang, T., Lv, Z., Liu, S. and Yang, H., 2019. "MOOCRC: A highly accurate resource recommendation model for use in MOOC environments," Mobile Networks and Applications, 24(1), pp.34-46.

[36] (2020, July 1). Retrieved from https://www.coursera.org/

[37] (2020, July 1). Retrieved from https://www.edx.org/

[38] (2020, July 1). Retrieved from https://www.khanacademy.org/

[39] Troussas, C., Krouska A., Virvou M, 2020, "Using a Multi Module Model for Learning Analytics to Predict Learners' Cognitive States and Provide Tailored Learning Pathways and Assessment," Virvou M., Alepis E., Tsihrintzis G., Jain L. (eds) Machine Learning Paradigms. Intelligent Systems Reference Library, vol 158. Springer, Cham.

On the Use of Websockets to Maintain Temporal States in Stateless Applications

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***Abstract*—This paper studies the use of Websockets to maintain temporal states in stateless applications. Concretely, it is used in a web-based application that calculates the propagation loss in outdoor environments. The reasons why Websockets are used and their limitations are discussed. A comparison with other similar technologies is also included.**

Keywords - web; WebSockets; communication protocols; real time web interfaces; stateless applications.

I. INTRODUCTION

Current web applications require fast communication between the server and the clients to produce close to real time updates on the web interface. If feedback is not received about the progress of the computations performed by the server, the user experience breaks apart. In [1], it is discussed that web page loading time increases user frustration and discomfort while browsing the web. This also is applicable to the waiting time between a user action and the webpage displaying the requested information.

The computational model that we will describe solves the waiting time problem for certain types of large computations. Once this computational model is described, REpresentational State Transfer (REST) and WebSockets will be analyzed, theoretically and experimentally, as the possible communication components to solve it.

Certain types of large computations need to hold a state in order to be performed or optimized. An algorithm that sorts a list of elements or looks for the shortest path on a graph needs those data structures as state. An algorithm that calculates propagation can be optimized by holding certain information as state and reuse it like if the state where a cache. But this state is temporal, once the computation has ended it is no longer needed to be held in the server.

In order to solve the waiting time problem, while performing a computation, the user must be informed of the progress of that computation. Ideally, by showing the current computation progress with as much detail as if it were the final result. The computation will be performed in the server and the representation update will be performed in the client, therefore, both processes will be concurrent. With this, solving the waiting time problem is transformed into finding the best way to hold that temporal state while the server informs the client about the progress of the computation.

Nowadays, lots of web applications and web services are based on the REST architectural style. REST has become very popular due to its simplicity and the fact that it builds upon the HyperText Transfer Protocol (HTTP), so developers are familiar with it. However, the REST architectural style has some disadvantages such as the lack of saving the stateful information between request-response cycles. In addition, there is no mechanism to send push notifications from the server to the client (to the web browser). This implies that it is hard to implement any type of services where the server updates the client without the use of client-side polling of the server or some other type of web hook. Consequently, every REST-based application is stateless, any state management tasks must be performed or initiated by the client.

Due to the fact that HTTP is half duplex, the server is not able to initiate a data transmission to a client as long as it has not been specifically asked for. Until now, web applications that needed bidirectional communication required an abuse of HTTP to poll the server for updates while sending upstream notifications as distinct HTTP calls. The disadvantages of using REST to maintain temporal states are mainly three. First, the server must use several TCP connections for each client: one for the client to send an initial request to the server where the operation to perform is described and a new one for each message that contains the progress or fraction of performed work. Second, the wire protocol has a high overhead, with each client-to-server message having an HTTP header. And third, the server is forced to maintain a mapping from the outgoing connections to the initial computation request to track which progress information must be sent to each client.

Combined, these disadvantages make REST hardly usable to perform computations that need temporal state on the server replicated context. In this context, multiple instances of the same server would run as separated process on the same or different machines, without one instance knowing the existence of the others. When a request is made it is handled by a load balancer that redirects it to one of the instances. Different connections from the same client may be answered by different instances of the server. Due to that, the server that received the initial computation request needs to share information with the other instances. This not only interfere with the idea of the replicated context, instances should not need to communicate, but also creates new synchronization problems. Some solutions make the client manage the temporal state and others make use of databases, both of which are slow and create an extra layer of complexity.

WebSockets [2]-[4] is a new protocol that provides a solution to overcome the aforementioned limitations. WebSockets uses a single TCP connection for traffic in both directions that allows a bidirectional, full-duplex, persistent

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socket connection between a web page and a remote server. Moreover, it is supported by all major web browsers.

Based on the two-way communication connection, the server can receive and process data, and can also send data back to the browser. Also, communication is more efficient than using HTTP if we focus on the size of the message and on the speed, especially for large messages, since in HTTP, for example, you have to send the headers in each request. This adds bytes.

According to the benchmarking done in [5] to compare the performance of HTTP vs WebSockets, the latter can be 50% faster than HTTP. This means that in many cases and depending on the needs of the project, WebSockets can be faster than traditional HTTP APIs. However, WebSockets is not the solution to all problems, other protocols perform certain tasks better than WebSockets does. In Section II, a comparison of several protocols vs. tasks is presented. A practical application of WebSockets in a real web-based simulation tool is described in Section III. Finally, conclusions are presented in Section IV.

II. Experimental results

To empirically test the performance differences between WebSockets and REST communication protocols, a demonstrative application was built. The design of this application aims to make the comparison as fair as possible, to let us inspect the strengths of both protocols.

If the application were to be built in the server replicated context, REST would have had major disadvantages. It would have been required to use a database to hold the temporal state or to hold it on the client and send it back and forth to the server in each request.

Therefore, the application will not be tested on this context. To hold the temporal state on the REST protocol, a random key is generated for each client. This key is provided to them as a response to their initial computation request. By providing this key, on each following request, the server will be able to know which temporal state belongs to each connection that requests a progress update on a computation. On the other hand, WebSockets will hold its temporal state on the single TCP connection that is created between the client and the server.

The developed demonstration takes as input a JSON document, which describes the computation to perform. Computations are a tree of actions, if one action is the child of another it will be performed after its father. On the other hand, if one action is in the same tree level of another they will be computed concurrently. Each computation has two steps, first a list of data is created according to the configuration on the JSON file and then the list is sorted with a certain criteria and sorting algorithm. The computations are performed on the server, while the client displays a graphical representation of the current position of the elements on the list. Multiple representations are available.

The server and the client communicate with REST or WebSockets allowing us to catch and dump the communication traces and inspect the transmitted packages with applications like Tcpdump or WhireShark.

Performing the same computations, the data shown in Table I have been collected with REST and WebSockets as communication protocols.

TABLE I. Comparison under nominal load

	REST	WebSockets
Packets	135.098	44.976
Transmitted data	27.634.885 bytes	4.723.849 bytes
Communications	22.481	22.480
Mean Time	86s 778ms	35s 226ms

For a single computation, 22.479 intermediate results have been sent from the server to the client to perform a close to real time graphical representation of its state. In order to archive that using WebSockets, an extra communication was needed to send the computation description to the server. In the case of REST, two extra communication where needed. One communication was used to send the computation to the server and another to inform the client that the computation had ended. Using WebSockets the client can be informed of the finalization of the computation by the server closing the channel.

In average, using WebSockets, there are two packets exchange between the client and the server, which leaves a total of 16 packets for stablishing the connection (8 packets) and closing it (8 packets). With REST, an average of six packets are exchanged between the server and the client per communication. This quantity should have been eight packets, but the libraries used try to reuse TCP connections by not always sending ‘FIN’ packets in order to save resources. Only 36 connections where closed in average along this computation. Additionally, REST performs Cross-Origin Resource Sharing (CORS) checks from time to time using a HTTP OPTIONS request. For this computation an average of 17 CORS checks were made.

REST not only uses around three times more packets along the computation, those packets are also almost six times heavier than WebSockets ones. This is because they need to carry a longer header. WebSockets is able to use a smaller header because the header is sent once, when the connection is stablished, and since the connection is never closed there is no need to resend it on every data transmission along that same connection.

The benefits of WebSockets not only can be seen on the amounts of data and packets transmitted but also in the time taken. Using REST, the communication will take more than double the time than with WebSockets.

Performing the smallest computation that the demo program is able to make, the following statistics have been recorded. This computation requires two updates of the user interface and which means a total of three and four communications for WebSockets and REST respectively.

With this second comparison, an improvement of the REST performance against WebSockets is expected. The theory around these protocols suggests that WebSockets should take longer to initiate the communication channel but, in the long run, with multiple data transmissions between the server and the client, it should surpass REST efficiency as seen on the first comparison.

TABLE II. COMPARISON UNDER MINIMUM LOAD

	REST	**WebSockets**
Packets	44	22
Transmitted data	7.127 bytes	2.489 bytes
Communications	4	3
Mean Time	0s 048ms	0s 015ms

Nevertheless, this expectation has not been backed up by the experimentally recorded data (see Table II). REST has improved its efficiency in the transmitted packets department but has not in the transmitted data and mean time ones. Examples of the traces used to calculate these statistics are included on Figure 1 for REST and on Figure 2 for WebSockets. The reason for this difference is that REST expends almost the same resources as WebSockets does for the whole communication just for the CORS request (blue section of Figure 1). Looking just at the time column of one single REST communication (one green section of Figure 1 and the proportional part of the red section) it can clearly be seen that is more efficient than the same communication on WebSockets protocol (blue section, red section and one green section of Figure 2).

So, if the CORS request is not taken into account, the expectations about REST are met. REST is a more efficient protocol for single sporadic data transmissions than WebSockets. On the other hand, WebSockets is more efficient for multiple communications even if their number is small.

III. PRACTICAL USE OF WEBSOCKETS IN A WEB-BASED APPLICATION

WebSockets is a stateful protocol, while HTTP connections are stateless. This means that WebSockets creates a connection that is kept alive on the server until the socket is closed and messages are exchanged bidirectionally. This particular feature is very useful to overcome three frequent problems that arise in the use and development of a web-based simulation tool like the one presented in [6] by the authors:

• It is desirable to display a progress bar in order to inform the users about the state of the calculations performed to provide the propagation loss. If the progress bar is not displayed, the users do not know how long it will take to complete the requested task.

• It is desirable to obtain partial results of the request made while it is being completed without interrupting this process. This combined with a progress bar not only informs about the lasting time, but also lets visualize earlier some of the requested information. Additionally, it entertains the users creating better user experiences.

• On the context of replicated servers, which is the case of our application, it is desirable to communicate always with the same server. At least during a computation. This allows to perform better optimizations without adding extra layers of complexity like databases or other ways of sharing information between the server instances. Avoiding this complexity is not only desirable from a design point of view. It also makes the application cheaper, no data is saved on disk, wasted computation time is minimal and no more than the necessary data is sent to the web.

In addition, authentication is also simplified by using Websockets. When using WebSocket, authentication is performed when the connection is established, so future requests under the same channel do not need to be authenticated again. This method greatly simplifies the authentication process. Therefore, Websockets improves the security of the system because there is no need of passing user credential in every request.

A web-based simulation [6] has been developed by the authors. This application is able to predict propagation losses in urban and rural environments by applying a semi-empirical algorithm. Now, the authors are improving that simulation tool. Deterministic methods are being included. These methods provide results more accurate but they have the disadvantage of consuming lots of resources (time and memory), so Websockets are very useful to inform the client about the state of the computations that are carried out in the server.

IV. CONCLUSIONS

WebSockets is a great protocol that solves three communication problems: 1) Sending multiple packets of data between the server and the client with a single communication negotiation required. 2) Creating a channel between a client and a server through which the client can receive notification from the server without polling. 3) Granting a stable connection between a client and a single instance of a replicated server that is behind a load balancer.

Those characteristics are exploitable to achieve close to real time updates on the progress and current state of long-lasting computations without major complications. While the computations are been performed, the progress or new calculated portions or approximations to the final solution are been sent to the client with a minimum performance loss and minimum design considerations. At the same time, the clients will be displaying fresh and updated information to the users with each packet received, creating a better user experience.

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REFERENCES

[1] P. Saed and Y. Yahya, "Loading time effects: A case study of Malaysian Examination Syndicate web portal," Proceedings of the 2011 International Conference on Electrical Engineering and Informatics, Bandung, 2011, pp. 1-5, doi: 10.1109/ICEEI.2011.6021664.

[2] I. Fette and A. Melnikov, The WebSocket Protocol, Internet Requests for Comments, RFC Editor, RFC 6455, World Wide Web Consortium, Cambridge, MA, USA, 2011, http://www.rfc-editor.org/rfc/rfc6455.txt [retrieved: September, 2020]

[3] B. Soewito, F. Christian, D. Gunawan, and I. Kusuma. “Websocket to Support Real Time Smart Home Applications”. Procedia Computer Science. 157. 2019. 560-566. 10.1016/j.procs.2019.09.014.

[4] Y. Wang, L. Huang, X. Liu, T. Sun, and K. Lei.. Performance Comparison and Evaluation of WebSocket Frameworks: Netty, Undertow, Vert.x, Grizzly and Jetty. 13-17. 2018. 10.1109/HOTICN.2018.8605989.

[5] HTTP vs Websockets: A performance comparison, available online at: https://blog.feathersjs.com/http-vs-websockets-a-performance-comparison-da2533f13a77[retrieved: September, 2020]

[6] A. Tayebi, J. Gomez, F. Saez de Adana, O. Gutierrez, and M. Fernandez de Sevilla, "Development of a Web-Based Simulation Tool to Estimate the Path Loss in Outdoor Environments using OpenStreetMaps [Wireless Corner]," IEEE Antennas and Propagation Magazine, vol. 61, no. 1, pp.123-129, Feb.2019.

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	::1	::1	TCP	88	57815 → 8081 [SYN] Seq=0 Win=65535 Len=0 MSS=16324 WS=64 TSval=1159601201 TSecr=0 SACK_PERM=1
2	0.000097	::1	::1	TCP	88	8081 → 57815 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=16324 WS=64 TSval=1159601201 TSecr=1159601201 SACK_PERM=1
3	0.000111	::1	::1	TCP	76	57815 → 8081 [ACK] Seq=1 Ack=1 Win=407744 Len=0 TSval=1159601201 TSecr=1159601201
4	0.000124	::1	::1	TCP	76	[TCP Window Update] 8081 → 57815 [ACK] Seq=1 Ack=1 Win=407744 Len=0 TSval=1159601201 TSecr=1159601201
5	0.003829	::1	::1	HTTP	512	OPTIONS / HTTP/1.1
6	0.003914	::1	::1	TCP	76	8081 → 57815 [ACK] Seq=1 Ack=437 Win=407360 Len=0 TSval=1159601204 TSecr=1159601203
7	0.004817	::1	::1	HTTP	382	HTTP/1.1 204 No Content
8	0.004842	::1	::1	TCP	76	57815 → 8081 [ACK] Seq=437 Ack=307 Win=407488 Len=0 TSval=1159601204 TSecr=1159601204
9	0.008987	::1	::1	TCP	88	57816 → 8081 [SYN] Seq=0 Win=65535 Len=0 MSS=16324 WS=64 TSval=1159601208 TSecr=0 SACK_PERM=1
10	0.009073	::1	::1	TCP	88	8081 → 57816 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=16324 WS=64 TSval=1159601208 TSecr=1159601208 SACK_PERM=1
11	0.009084	::1	::1	TCP	76	57816 → 8081 [ACK] Seq=1 Ack=1 Win=407744 Len=0 TSval=1159601208 TSecr=1159601208
12	0.009093	::1	::1	TCP	76	[TCP Window Update] 8081 → 57816 [ACK] Seq=1 Ack=1 Win=407744 Len=0 TSval=1159601208 TSecr=1159601208
13	0.009661	::1	::1	TCP	504	57816 → 8081 [PSH, ACK] Seq=1 Ack=1 Win=407744 Len=428 TSval=1159601208 TSecr=1159601208 [TCP segment of a reassembled …
14	0.009687	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=1 Ack=429 Win=407360 Len=0 TSval=1159601208 TSecr=1159601208
15	0.009988	::1	::1	HTTP	204	POST / HTTP/1.1 (application/json)
16	0.010006	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=1 Ack=557 Win=407232 Len=0 TSval=1159601209 TSecr=1159601209
17	0.011136	::1	::1	HTTP	349	HTTP/1.1 200 OK (text/html)
18	0.011164	::1	::1	TCP	76	57816 → 8081 [ACK] Seq=557 Ack=274 Win=407488 Len=0 TSval=1159601210 TSecr=1159601210
19	0.015465	::1	::1	TCP	503	57816 → 8081 [PSH, ACK] Seq=557 Ack=274 Win=407488 Len=427 TSval=1159601214 TSecr=1159601210 [TCP segment of a reassemb…
20	0.015506	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=274 Ack=984 Win=406784 Len=0 TSval=1159601214 TSecr=1159601214
21	0.015742	::1	::1	HTTP	121	POST / HTTP/1.1 (application/json)
22	0.015756	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=274 Ack=1029 Win=406720 Len=0 TSval=1159601214 TSecr=1159601214
23	0.016699	::1	::1	HTTP	372	HTTP/1.1 200 OK (application/json)
24	0.016720	::1	::1	TCP	76	57816 → 8081 [ACK] Seq=1029 Ack=570 Win=407168 Len=0 TSval=1159601215 TSecr=1159601215
25	0.026465	::1	::1	TCP	503	57816 → 8081 [PSH, ACK] Seq=1029 Ack=570 Win=407168 Len=427 TSval=1159601224 TSecr=1159601215 [TCP segment of a reassem…
26	0.026492	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=570 Ack=1456 Win=406336 Len=0 TSval=1159601224 TSecr=1159601224
27	0.027741	::1	::1	HTTP	121	POST / HTTP/1.1 (application/json)
28	0.027777	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=570 Ack=1501 Win=406272 Len=0 TSval=1159601225 TSecr=1159601225
29	0.029829	::1	::1	HTTP	374	HTTP/1.1 200 OK (application/json)
30	0.029864	::1	::1	TCP	76	57816 → 8081 [ACK] Seq=1501 Ack=868 Win=406912 Len=0 TSval=1159601227 TSecr=1159601227
31	0.042793	::1	::1	TCP	503	57816 → 8081 [PSH, ACK] Seq=1501 Ack=868 Win=406912 Len=427 TSval=1159601239 TSecr=1159601227 [TCP segment of a reassem…
32	0.042815	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=868 Ack=1928 Win=405824 Len=0 TSval=1159601239 TSecr=1159601239
33	0.043037	::1	::1	HTTP	121	POST / HTTP/1.1 (application/json)
34	0.043054	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=868 Ack=1973 Win=405824 Len=0 TSval=1159601239 TSecr=1159601239
35	0.045428	::1	::1	HTTP	230	HTTP/1.1 200 OK
36	0.045455	::1	::1	TCP	76	57816 → 8081 [ACK] Seq=1973 Ack=1022 Win=406720 Len=0 TSval=1159601241 TSecr=1159601241
47	5.009046	::1	::1	TCP	76	8081 → 57815 [FIN, ACK] Seq=307 Ack=437 Win=407360 Len=0 TSval=1159606165 TSecr=1159601204
48	5.009082	::1	::1	TCP	76	57815 → 8081 [ACK] Seq=437 Ack=308 Win=407488 Len=0 TSval=1159606165 TSecr=1159606165
49	5.009141	::1	::1	TCP	76	57815 → 8081 [FIN, ACK] Seq=437 Ack=308 Win=407488 Len=0 TSval=1159606165 TSecr=1159606165
50	5.009172	::1	::1	TCP	76	8081 → 57815 [ACK] Seq=308 Ack=438 Win=407360 Len=0 TSval=1159606165 TSecr=1159606165
51	5.047380	::1	::1	TCP	76	8081 → 57816 [FIN, ACK] Seq=1022 Ack=1973 Win=405824 Len=0 TSval=1159606203 TSecr=1159601241
52	5.047415	::1	::1	TCP	76	57816 → 8081 [ACK] Seq=1973 Ack=1023 Win=406720 Len=0 TSval=1159606203 TSecr=1159606203
53	5.047489	::1	::1	TCP	76	57816 → 8081 [FIN, ACK] Seq=1973 Ack=1023 Win=406720 Len=0 TSval=1159606203 TSecr=1159606203
54	5.047522	::1	::1	TCP	76	8081 → 57816 [ACK] Seq=1023 Ack=1974 Win=405824 Len=0 TSval=1159606203 TSecr=1159606203

Figure 1. REST packet trace.

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	::1	::1	TCP	88	53795 → 8080 [SYN] Seq=0 Win=65535 Len=0 MSS=16324 WS=64 TSval=1149975839 TSecr=0 SACK_PERM=1
2	0.000096	::1	::1	TCP	88	8080 → 53795 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=16324 WS=64 TSval=1149975839 TSecr=1149975839 SACK_PERM=1
3	0.000111	::1	::1	TCP	76	53795 → 8080 [ACK] Seq=1 Ack=1 Win=407744 Len=0 TSval=1149975839 TSecr=1149975839
4	0.000124	::1	::1	TCP	76	[TCP Window Update] 8080 → 53795 [ACK] Seq=1 Ack=1 Win=407744 Len=0 TSval=1149975839 TSecr=1149975839
5	0.002425	::1	::1	HTTP	486	GET / HTTP/1.1
6	0.002450	::1	::1	TCP	76	8080 → 53795 [ACK] Seq=1 Ack=411 Win=407360 Len=0 TSval=1149975841 TSecr=1149975841
7	0.003066	::1	::1	HTTP	205	HTTP/1.1 101 Switching Protocols
8	0.003085	::1	::1	TCP	76	53795 → 8080 [ACK] Seq=411 Ack=130 Win=407616 Len=0 TSval=1149975841 TSecr=1149975841
9	0.004154	::1	::1	WebSocket	212	WebSocket Text [FIN] [MASKED]
10	0.004177	::1	::1	TCP	76	8080 → 53795 [ACK] Seq=130 Ack=547 Win=407232 Len=0 TSval=1149975842 TSecr=1149975842
11	0.006424	::1	::1	WebSocket	130	WebSocket Text [FIN]
12	0.006448	::1	::1	TCP	76	53795 → 8080 [ACK] Seq=547 Ack=184 Win=407616 Len=0 TSval=1149975844 TSecr=1149975844
13	0.009545	::1	::1	WebSocket	132	WebSocket Text [FIN]
14	0.009588	::1	::1	TCP	76	53795 → 8080 [ACK] Seq=547 Ack=240 Win=407552 Len=0 TSval=1149975847 TSecr=1149975847
15	0.011413	::1	::1	WebSocket	78	WebSocket Connection Close [FIN]
16	0.011439	::1	::1	TCP	76	53795 → 8080 [ACK] Seq=547 Ack=242 Win=407552 Len=0 TSval=1149975848 TSecr=1149975848
17	0.012041	::1	::1	WebSocket	82	WebSocket Connection Close [FIN] [MASKED]
18	0.012064	::1	::1	TCP	76	8080 → 53795 [ACK] Seq=242 Ack=553 Win=407232 Len=0 TSval=1149975849 TSecr=1149975849
19	0.012544	::1	::1	TCP	76	8080 → 53795 [FIN, ACK] Seq=242 Ack=553 Win=407232 Len=0 TSval=1149975849 TSecr=1149975849
20	0.012570	::1	::1	TCP	76	53795 → 8080 [ACK] Seq=553 Ack=243 Win=407552 Len=0 TSval=1149975849 TSecr=1149975849
21	0.013221	::1	::1	TCP	76	53795 → 8080 [FIN, ACK] Seq=553 Ack=243 Win=407552 Len=0 TSval=1149975850 TSecr=1149975849
22	0.013260	::1	::1	TCP	76	8080 → 53795 [ACK] Seq=243 Ack=554 Win=407232 Len=0 TSval=1149975850 TSecr=1149975850

Figure 2. WebSockets packet trace.