Adaptive Strategies in Web-based Learning Systems: A Comparative Survey

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Abstract. The rapid evolution of the Web as the place where to spread and share information, and the growing personalisation of Web applications, have given rise to many interesting approaches enhancing current Web-based learning systems.
In particular, our research activity has led to the definition of an innovative adaptive strategy drawn upon the short-term observation of users seeking-behaviour, in order to capture as soon as possible a good approximation of their interests. Therefore, this paper aims at (i) surveying the existing adaptive strategies based on a short, middle and long-term perspective and (ii) at fostering a quite exhaustive comparison between our peculiar approach and other similar adaptive processes.

1 Introduction

The widespread use of the Web as the privileged place of knowledge sharing has induced a wealth of instructional opportunities, leading to the development of specific and advanced platforms whose aim has been to provide well-organised on line courses and teaching or tutoring services. The whole of these instruments and their underlying techniques has given rise to a new educational paradigm, known as e-learning.

In this way, the Web has turned from a place where to simply release educational material, into the chosen place where to carry out most of the learning process, that becomes a social process, through the implementation of virtual learning environments drawn upon open, flexible and highly personalised dynamics.

In the light of this new approach, individualisation and the presence of some sort of sophisticated adaptive procedure, able to modify every single navigation path [21], may lead from a content-centred vision of the learning process to a learner-centric approach where contents are modified according to a model of the learners. In particular, this model depends on their peculiar background, social role, culture and, most of all, on the *contingent situation* they are living.

According to these precise requirements we have defined a model for short-term content adaptation, in order to capture the instantaneous interest of users

by observing their behaviour on a very short amount of time and, then, adjusting the information a web-based learning application provides according to the inferred short-term user profile.

This is the real novelty of our adaptive approach [3–5, 8], since a concentration of efforts focuses on long-term profiling, that requires a great extent of empirical study and analysis of the seeking-behaviour of the users, by following their actions attentively over a long time, in order to deduce a complex and precise user model (see details in Section 3).

Although these attempts have produced very interesting results, they are quite *slow* and users expectations of a rapid fulfilment of their needs are often frustrated. On the contrary, our short-term observation, even though entailing an imprecise deduction of information about users, seems to fill the gap between their expectations and the technological offer.

The context where the short-term adaptive behaviour is observed is the VICE project, an e-learning system with Semantic Web support (see Section 2).

2 The VICE project

The VICE (Virtual Continuing Education) project aims at developing an innovative methodology and platform to build high-level e-learning applications with a strong technological support.

VICE wants to support instruction in the ICT (Information and Communication Technologies) area, and in particular, the project focuses on assisting the development and growth of small business firms, by instructing professionals about the ICT themes and the security problems.

The teaching method will follow the blended approach, i.e., aside a small traditional teaching activity, most of the instructional process takes place online.

2.1 Goals

The VICE project is strictly drawn upon the Semantic Web technology and the use of Artificial Intelligence techniques, in order to cope with the adaptive aspects of the educational contents fruition. Hence, the innovative platform VICE intends to realise is expected to allow the creation of a repository where to store and access LOs, properly enriched with metadata along with a formal semantics that gives them meaning. Then, various artificial agents can benefit from this information to query the content of the repository and to automatically compose LOs in lessons or courses, so as to satisfy some didactic goal and, thus, to tailor learning paths to specific cognitive needs of the users. Hence, whenever the user poses a query or follows a link, the system analyses this request to individuate a profile. Then the system transforms the retrieved answer according to the inferred interests and preferences.

Within the wider framework of the VICE project, the querying activity is performed by the *pedagogical wizard*. It forces LOs representation to support

pedagogical and semantic metadata, interpreted according to the wizard knowledge that is organised as a coordinated set of ontologies written in the OWL language. In particular, the pedagogical wizard interprets LOs as the necessary information to support a didactic process. Hence, by means of a pedagogical taxonomy, it can classify LOs according to their style, to their level of difficulty and to their relative importance in a specific learning process. Therefore, the pedagogical wizard benefits of this information to compose LOs in lessons and courses, with the warranty that the composition is uniform and balanced with respect to the pedagogical criteria specified by the user. An intelligent agent, that acts by planning the lesson or course with Artificial Intelligence techniques, performs this composition activity.

Another agent in the wizard is the adaptive filter that intercepts queries to the repository and uses them to construct a user profile. Then, it transforms the answer of the repository according to the adaptive strategy. The profile deduced by the filter is a model of the querying user, which is devoted to code his interests and characters. While interests are intended to be short-term goals the user wants to fulfil, characters are considered as long-term information describing the user preferences and capabilities.

In particular, we have focused our research activity on the short-term behaviour that constitutes the real novelty in our adaptive approach [4, 5, 8]. In fact, the long-term adaptive model is a natural extension of the short-term model, and is comparable with many existing approaches, see Section 3.

The goal of the adaptive strategy performed by our filter is to model two behaviours: 1) *convergence* of the transformation process; 2) *changes of interest*.

Precisely, in the hypothesis that a sequence of queries represents an attempt to satisfy an interest of the user, we expect that every query in the sequence refines the interest, until a satisfying result is found. Hence, the transformation process should result in a series of answers that are closer and closer to the satisfaction of the user interest. This series of answers should converge with the same speed as the sequence of queries.

Therefore, the filter must be able to segment the flow of queries from a user in sequences each of one converging to the full expression of a single interest, until the interest gets satisfied.

The property the filter is called to preserve is informally stated as "to a small variation in the profile, a small variation in applied transformation corresponds", hence the need for a mathematical model. In fact, the model is more precise and what it does really preserve is the convergence speed.

According to this perspective, the filter should sense also the changes of interest in the flow of queries issued by a user. Thus, given a sequence of queries, and an initial user profile, one should consider when the generated sequence of user profile terminates and a lack of convergence in the sequence occurs. In fact, since the user may change his interests after issuing a few queries, the profiling activity of the filter should be restarted by generating a fresh user profile: it means that the initial point of every sequence of user profiles is a neutral profile. This restart is called, precisely, a change of interests. Hence, the mathematical

model captures a change of interest by observing, step by step, the sequence of generated profiles [5].

To conclude, the filtering action, guaranteed by the mathematical model, is drawn upon two algorithms: the *analyser*, extracting information from the query and updating the user profile, and the *transformer*, choosing a transformation, parametrised by the user profile, to apply to the result.

Two elements strictly related compose the mathematical model: the user space model, that represents users characters and interests (as well as queries can be interpreted as *profiles*), and the transformation space, that represents admissible ways to manipulate results from the repository, according to the user profile.

The close link between these two spaces ensures the short-term behaviour, since our model impose that the convergence speed of a sequence of queries is reflected in the convergence speed of the sequence of results.

3 A Comparative Survey

The international scenario offers a wealthy amount of projects aiming at realising innovative approaches, in order to radically improve the users learning experience thanks to the most advanced communication technologies.

As a matter of fact, the Web has been *extended* [9], turning from a simple information retrieval and communication tool into a smart and semantic space, so as to web-based learning systems emphasise the freedom of accessing resources and enhance the possibility to choose the most appropriate learning or cognitive style [14].

Since the interest of users in different approaches to the educational resources is a fundamental subject matter of adaptivity, several applications have paid much attention to define a set of instructional strategies in order to meet users individual learning styles and preferences and, thus, to improve their performance. In our opinion, some projects may be considered as particularly representative of a class of approaches, thus, in the following, we focus on their relevant aspects.

A very interesting approach to personalisation is based on the complementary pair of authoring systems **AHA!** and **MOT** [22], whose main objective is to provide authors with specific tools that help them to supplement their adaptive applications by designing as many assortments and combinations of learning styles as possible (individual learning styles are assessed through a registration form where users can select their favourite instructional strategy).

What is most noteworthy in this project, the users' browsing behaviour allows the system to improve its performance by inferring their preferences and keeping them up to date from time to time.

The cooperation between IBM and MIT gave rise to a pilot study of a system, whose core is the **Dynamic Assembly Engine** [12], to automatically assemble LOs in personalised paths, by ordering the learning resources in a logical sequence. Actually, once a query has been submitted, the system returns a list of the most relevant results matching the users' requirements, according to their

educational role. The main concern of this work is to find a solution not only to select the most appropriate resources to a specific learning path, but to connect them in a well-organised *corpus* too, tailored to specific cognitive needs. The framework of the Dynamic Assembly Engine is particularly close to VICE, see Section 2, since a XML federated repository, in which web resources are stored, and a strict correspondence of LOs content and their metadata to user needs work together to make this approach feasible. The accuracy of the system is guaranteed by the knowledge the application has of users' queries, and the coherence of the path is achieved by presenting objects that are closely related with one another, meeting the search parameters.

The German prototype **ELENA** [11], based on the **Edutella** P2P infrastructure [20], is another valuable research work in the domain of personalised supports for students in an e-learning network, in order to create an adaptive Semantic Web environment. The main contribution of ELENA is the creation of *smart spaces for learning*, defined as educational service mediators, based on Semantic Web and Artificial Intelligence technologies. These spaces provide students with an exhaustive description of those learning resources that meet their profile, by allowing them to access any kind of network-connected repository. The keystone of this project, the **Personal Learning Assistant** (PLA), is expected to present a focused list of learning services. The action performed by the PLA, refers to the user dynamic profile, in order to extend queries by adding restrictions, variables, preferences, goals, etc., and to customise search results.

The close likeness between all these works and VICE is due to the fact that the adaptivity the filter provides in our work concerns the capability to take in account all the users' features (gathered thanks to their navigational background and the actions performed while carrying out their searches), in order to customise educational contents and make them fulfil specific cognitive needs. In this way, the filter allows users to orientate themselves in the guided usage of the knowledge stored in the repository, through AI and Semantic Web technologies. Noticeably, the filter model is conceived to address the short-term behaviour of users, while the adaptive approaches described so far have been developed to exhibit a long-term understanding. The long-term approach requires a great extent of empirical study and analysis of the navigational behaviour of the users, by keeping track of their actions for a long amount of time (e.g., a whole day [23]), in order to obtain an accurate description of the users and their preferences. On the contrary, our filter is expected to capture as soon as possible (less than a dozen of observations) a pretty good approximation of users interests. Due to this peculiarity, our short-term observation entails an imprecise deduction of information about users in order to understand their changes of interest (see Section 2.1) and, as inferred by the sequence of queries, to refine the acquired knowledge about users as quickly as possible.

Other interesting results in the e-learning field, especially as far as pedagogical approaches and learners model are concerned, come from the peculiar vision of the large and diverse **ELeGI** project [25].

In general, the underlying motivations of ELeGI initiative are deeply-rooted in the criticism of current e-learning approaches, too focused on contents and on the best way to transfer them to learners. Therefore, the mission of this project is to foster a new educational paradigm, whose core is the learner, based on the construction of a functional base of knowledge, rather than on the simple information transfer.

As a matter of fact, learning has to be conceived as a social and constructive activity, made of a strong interaction and communication among all those attending the educational process, that is, students, teachers, tutors and other trainers. Thus, to radically advance the users learning experience, the ELeGI project draws its vision upon a strictly human-centred design [7].

In such a context, according to the emerging Grid networking technology [17], ELeGI project tends towards the creation of dynamic, wide and networked environments for virtual learning communities, by connecting a distributed computer simulation system. Hence, its aim is to support collaborative, experiential-based and highly personalised approaches for ubiquitous learning (for anyone, anytime and anywhere, by enabling full interoperability with existing software). In other words, its intention is to make it easier for people to benefit from a large-scale sources and resources sharing, in order to provide global access to the knowledge and to facilitate its creation [6, 15, 26].

In the wider framework of the ELeGI project, three main research areas can be identified: 1) towards Grid-compliant prototypes of existing learning environments; 2) Grid technologies: applications and interfaces; 3) e-learning: pedagogical approaches, learners model, environments and technologies.

Since our attention is mainly focused on the third aspect, among the various research works related to ELeGI, **edCity** project [13] has aroused our lively interest.

EdCity is a large scale, scenario-driven model of a virtual city, whose aim is to facilitate learning for anyone, anytime and anywhere, through the fusion of the real and the virtual. In fact, the most noteworthy aspect of this project is that the system is expected to meet the needs of a wide range of communities, different cultures and social organisations that compose a city, by learning to adapt itself to the particular interests and preferences of the users. Hence, it will be able to generate diverse scenarios satisfying specific needs, by combining different information and creating relevant game-like environments.

Having said this, despite (i) the peculiarity of such adaptive approaches as the above mentioned edCity, (ii) the common denominator provided by the technologies of the Semantic Web [16, 18, 19, 24], (iii) the user-centred design, and (iv) the purpose to enable the creation of federated networks, methods and bases of ELeGI and our VICE project do not show any other contact.

In fact, in the ELeGI research initiatives, adaptivity (either short-term, or long-term), Semantic Web and the most advanced communication and information technology do not play a leading role. In a certain sense they are taken for granted, as the obvious base on which to found a new approach, completely focused on the learner and on the complex dynamics of the learning experience.

The Grid approach claims to represent a quality leap in the definition of learning environments (in which knowledge is always and freely accessible) and in the pursuit of service ubiquity; hence, traditional Web Services have become more and more old-fashioned: the future shall be the holistic Grid approach [10].

We must admit that this particular perspective may lead to new possibilities and ideas so as to realise a better support to the didactic activity, and that, on the long run, it may represent an interesting modernisation in the area of the e-learning. However, it offers a too generic and, in some way, simplistic approach to the hoary problem related to information and resources retrieval and, most of all, to their combination in effective learning paths.

4 Conclusions

Aim of this work has been to compare the results of our research work in adaptive e-learning systems with other recent works in literature.

Our research activity is performed in the context of the VICE project, in which we are involved as responsible for the definition of an innovative short-term adaptive filter model. Precisely, our strategy is expressly conceived to profile users in a very short amount of time (less than a *dozen* of observations) and, then, to adjust the contents according to the inferred information.

Moreover, in the light of the up-to-date recent e-learning projects incorporating an adaptive processes, a comparison between our approach and the most recent ones was due.

With this respect, we can say with a certain confidence that, as far as we know, all adaptive strategies in literature operate by deducing accurate users profiles within a long-term perspective.

This survey clearly shows that the VICE project is a state-of-the-art system, with some innovations like its adaptive strategy.

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