Application of Semantic Web Technologies to Facilitate Use of E-Learning System on Mobile Devices

Boban Vesin, Aleksandra Klašnja-Milićević and Mirjana Ivanović

Abstract Evaluation of mobile learning components is an important and popular research topic in the field of education. We have developed the modern e-learning system, named Protus 2.1. In order to personalize the learning process and adapt content to each learner, this system uses strategies that have the ability to meet the needs of learners and perform the adaptation of teaching materials. This paper presents the design and implementation of mobile version of Protus 2.1 which will allow its comfortable use for adapting the learning contents to the learners competences, to the learners context and to his/her mobile device.

Keywords Mobile learning · Semantic web · Ontology · Tutoring system

1 Introduction

The essential goals and functionalities of e-learning systems are to offer learners capability to access courses from various platforms, any time and anywhere [14]. Mobile learning is based on use of mobile devices in an educational process. Mobile technologies can provide a way to engage learners [10] and are recognized as an emerging technology to facilitate educational strategies that exploit individual learners' context [5].

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Recent developments and technological achievements in communications and wireless networks have resulted in mobile devices (e.g., mobile phones, tablets) becoming widely available, more convenient, and less expensive [14]. However, mobile learning brings challenges in the adequate processing and delivering learning content [15]. Modern trends dictate the content is accessible and easily adaptable to different kinds of devices.

Semantic web presents a collaborative environment in which the information has a meaning understandable to machines [3]. To achieve this goal, addition of metadata (e.g., XML, RDF, Ontologies, or RSS) and adaptation rules [10] to existing e-learning systems are required.

In our previous research, we implemented tutoring system named Protus 2.1 (PROgramming TUtoring System) that is used and tested for programming topics. Protus is designed to recognize the behaviour patterns of learners and identify their learning styles, form clusters (categories) of similar learners, based on their learning styles and categorize teaching materials based on their rating and present recommended learning materials for learners.

Some parts of system are implemented using ontologies and adaptation rules for knowledge representation [13]. All Protus 2.1 components are implemented in the form of educational ontologies, while personalisation options are presented with SWRL (Semantic Web Rule Language) adaptation rules. The system is completely operative but only on desktop computers. In order to increase the usability of the system on mobile devices with smaller screens, it is necessary to perform dynamic adaptation of user interface to a lower resolution screens. This paper presents the implementation of mobile version of Protus 2.1 in order to provide same e-learning functionalities to mobile users. It is necessary to adapt the *Learner interface ontology* of Protus 2.1 with adding certain SWRL rules that would select the appropriate form of presentation for particular devices. Although this paper shows an application in programming tutoring system considered approach can be applied in a variety of other learning domains.

The rest of the paper is organized as follows. In the Sect. 2 appropriate related work is analysed. Section 3 describes components of our system, including modified ontologies and dynamic selection of presentation. User interface adapted to mobile devices is described in Sect. 4. Results of the Protus 2.1 testing are presented in Sect. 5. Section 6 concludes the paper.

2 Related Work

Nowadays learners can use smartphones, portable video consoles, and GPS navigators for learning [10]. Numerous research papers has focused on several broad areas of inquiries such as the effectiveness of mobile learning and the development of systems for mobile learning [4]. Different institutions have been concentrating their research efforts on mobile learning and have proposed various content processing techniques. Some of the techniques focus on the design of adaptive and personalized

learning systems. Learners in those systems [2, 5, 8, 15] are provided with adaptive and personalized learning experiences that are tailored to their particular educational needs and mobile devices.

Semantic applications are based on the idea of systems being able to extract meaning from information on the web and to provide personalized services and information according to user needs [10]. Authors in [12] introduced a systematic approach to service personalisation for mobile learners in pervasive environments. They presented service-oriented framework that integrates semantic technologies for learner modelling and personalised reasoning. The use of Semantic web technologies and in particular ontologies for development of mobile application for preschool cognitive skills learning is presented in [1]. CogSkills mobile application is developed to evaluate specific knowledge model.

The research purpose of majority of mobile learning studies focuses on effectiveness and mobile learning system design [14]. Surveys and experiments were used as the primary research methods. The effects of mobile learning on learners achievements and attitude were presented in [10]. The study revealed that mobile learning keeps the learners engaged, and it is possible to deliver learning that is authentic and informal via the mobile learning technologies [10].

Mobile phones and tablets are currently the most widely used devices for mobile learning [14]. Therefore it is important to adapt e-learning systems to variety of technologies. Not many e-learning systems exist that are adapted for wide range of devices with different screen sizes. Mainly, those systems are adapted specifically for mobile devices or only for desktop computers.

Although there are many tools for mobile learning of programming languages, Protus 2.1 stands out by using personalization for adapting content to specific users [7]. Our goal is to enable the use of the Protus 2.1 both through mobile application and via web browser, using a single user account.

In this paper, we will present the possibilities for adaptation of an existing tutoring system to cope with diversity of platforms on which it runs. System will also provide functionalities for testing of acquired knowledge over mobile devices unlike many of those systems [4, 7, 10, 14].

The main contributions of the paper are (1) the learning approach adopted to take advantages of the learners context (mobility and specific needs) (2) the flexible architecture of Intelligent learning system and its modular and fine grained components (3) the mechanism provided for handling the learners context and the model on which it is based and (4) the semantic and ontological descriptions of the learners mobile context, the learning approach as well as the components and services provided by the system.

3 Protus 2.1

Protus 2.1 is a tutoring, interactive system that allows learners to use teaching material and test acquired knowledge for introductory Java programming course [13]. Learner's interface of Protus 2.1 is a series of web pages that provide: taking lessons

and testing learner's knowledge. All data about a learner and his progress in the course, as well as data about tutorials, tests and examples are stored on the system's server. Learners attend courses through the web interface [9] that:

- review of the offered courses and teaching materials,
- various display of teaching materials adapted to learning styles,
- testing of acquired knowledge,
- communication with the mentor and other learners,
- reports about progress, test results, coursework and their own learning styles.

Due to the highly fragmented mobile technology trends and rapidly evolving standards, there is no single solution to make existing educational content working for every possible mobile or desktop device. Educators are forced to design new learning content or reformat existing learning materials for delivery on different types of mobile devices [15].

Tutorials and tests in Protus 2.1 are structured in html, therefore it is suitable for presenting on different devices. In order to adapt Protus 2.1 itself to different devices, its user interface should be flexible and scalable, based on semantic web and appropriate rules.

3.1 System Architecture of Protus 2.1

From a learner's perspective, learning content is always the key element in education delivery, not the mobile technology itself. Implemented architecture of Protus 2.1 improves the ontology utilization, where the representation of each component is made by a specific ontology (Fig. 1): *Domain ontology*, *Learner model ontology*, *Task ontology*, *Teaching strategy ontology* and *Learner interface ontology*. Various adaptation conditions in Protus 2.1 were captured in the body of SWRL rules. As a result of the execution of rules, recommendations in the form of various content presentations are generated [6].

Protus 2.1 has achieved a remarkable impact on learners self-learning [9]: learners have gained more knowledge in less time. The next step in development of the system is its adaptation to mobile devices, i.e. to provide more possibilities to its users, because learners can learn more conveniently if they are not limited by specification of hardware used in learning process.

Current form of the Protus 2.1 components allow easy maintenance of the system. Changes will have to be made in *Learner interface ontology* and to SWRL adaptation rules for selection of presentation templates. User interface must be designed to adapt the application to the screen resolution of mobile devices. Current implementation is undertaken in four stages:

- design of the learner interface layouts for different screen resolutions,
- adaptation of *Learner interface ontology* to precisely designed layouts,
- design of the required SWRL rules that selects presentation layout and
- testing on different devices.

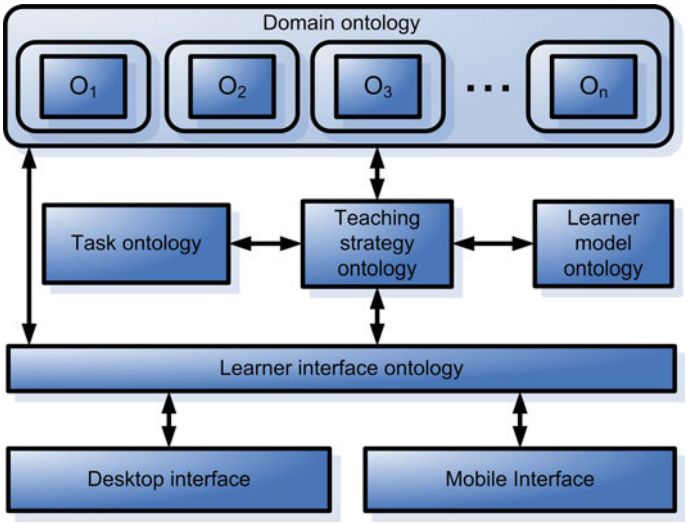


Fig. 1 Protus 2.1 Semantic web architecture

Learner Interface Layouts. In order to provide adapted user interface of the existing tutoring system for mobile devices, appropriate changes must be incorporate only to the *Learner interface ontology*. Therefore, the advantage of this approach is that learners will basically use the same system over different devices, but with appropriately adapted user interface (Fig. 2).

In case of higher screen resolution of device, the first layout (that simultaneously presents all page segments) will be presented. When requests arrive from devices with smaller resolution screen, only chosen page segments will be presented.

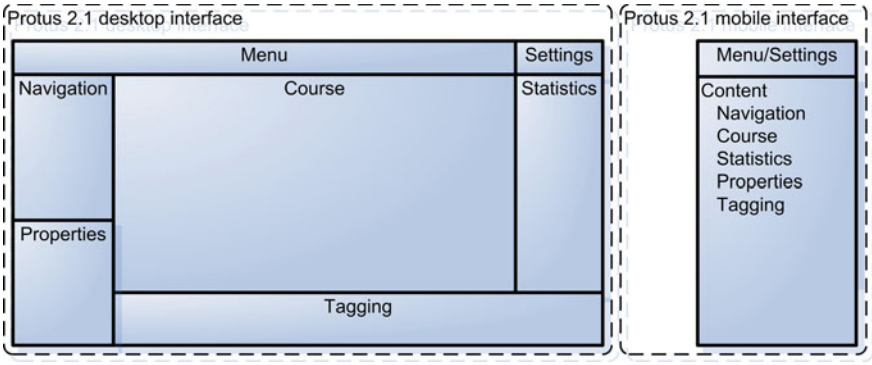


Fig. 2 Different user interface layouts in Protus 2.1

Learner Interface Ontology defines final stage of course implementation. System reads a decision from the *Teaching strategy ontology*, and based on that decision it creates presentation for the particular learner and device. System generates an interface for the learner based on the chosen layout. *Learner interface ontology* will be used to specify the content and layout of the pages and to standardize the content and query vocabulary.

Adaptation Rules for Mobile Version of Protus 2.1. Rule-based reasoning enables a more expressive method for inference of processes and interaction in Semantic web system [12]. While *Learner model ontology* of Protus 2.1 provides the representations of learners needs, reasoning mechanisms are used to infer presentation and services of the system in terms of the learner model and application context. These mechanisms are part of the *Task ontology* and the *Teaching strategy ontology* that presents how the adaptation is carried out. Finally, the *Interface ontology* presents result of communication among the different components of the Protus 2.1 architecture.

SWRL rules are one of the most popular forms of knowledge representation [11]. Rules used in Protus 2.1 are:

- *Learner modelling rules* that add knowledge about a learner, inferring new learner features from other already existing features of that learner. They are necessary for the building and updating of the of *Learner model*.
- *Adaptation rules* that define strategies of adaptation, taking into account domain features, system adaptation goals, user features, context and used presentation methods. Rules that will alter presentation layouts of Protus 2.1 fall in this category.

At the presentation level, Protus 2.1 requests information about the current device and current course level to make decision which element will be presented on the screen and in which form. Adaptation rule for selecting appropriate presentation layout is:

```
Learner(?x)^Interaction(?y)^hasInteraction(?x,?y)^
isPartOf(?r,?y)^Resource(?r)^isRecommended(?r, true) ^
Presentation (?p)^consistOf(?p, ?r)^Decision(?d) ^
implements(?d,?p)^ofType(?mob, true)^UI(?u)^
creates(?p,?u)^hasType(?u,?t)^UIType(?t)->hasLayout(?t,mobile)
```

Therefore, if learner x has interaction with certain resource, and for that particular session system determined that mobile device has been used, than presentation layout for mobile devices should be used. Similar rule is triggered when requests come from a desktop device.

Exactly one of these rules is triggered every time learner sends request to server, and based on the response, appropriate user interface will be generated.

4 User Interface for Mobile Devices

Proposed modified ontology architecture will provide comfortable use of Protus 2.1 on different devices. The user interface is generated based on the ontology data and SWRL adaptation rules. Protus 2.1 functionalities and pages viewed from a mobile device are: for presenting lectures Fig. 3, an overview of the courses—Fig. 4, page with personal course statistics for a learner Fig. 5.

Protus 2.1 application dynamically selects the layout based on the dimensions of the used screen and selected teaching material. This ensures that a student is clearly presented with the educational material and navigation options in every moment. We tested correctness of display on different platforms and ensured that education material is displayed as on desktop computers.

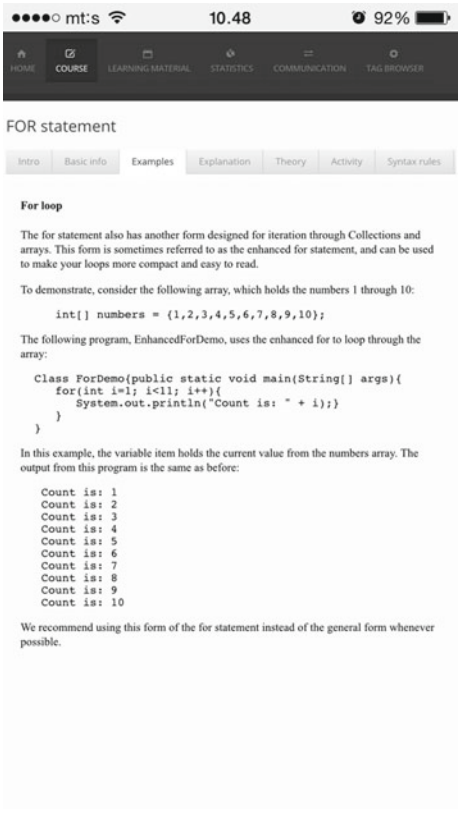


Fig. 3 *Course* Page

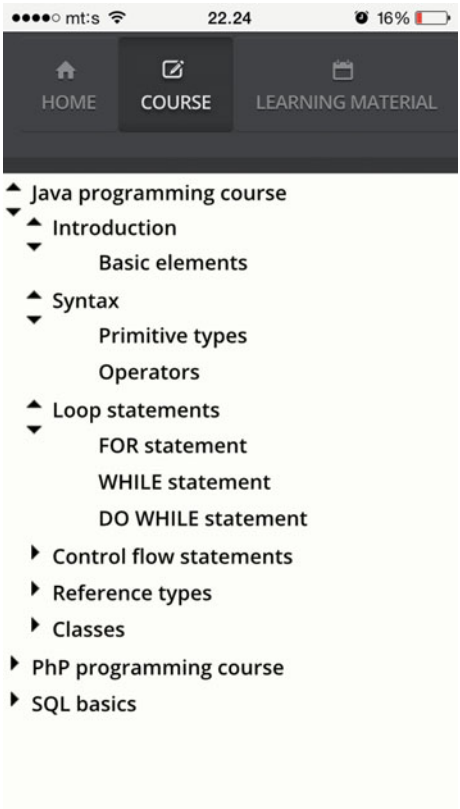


Fig. 4 *List of Courses* Page

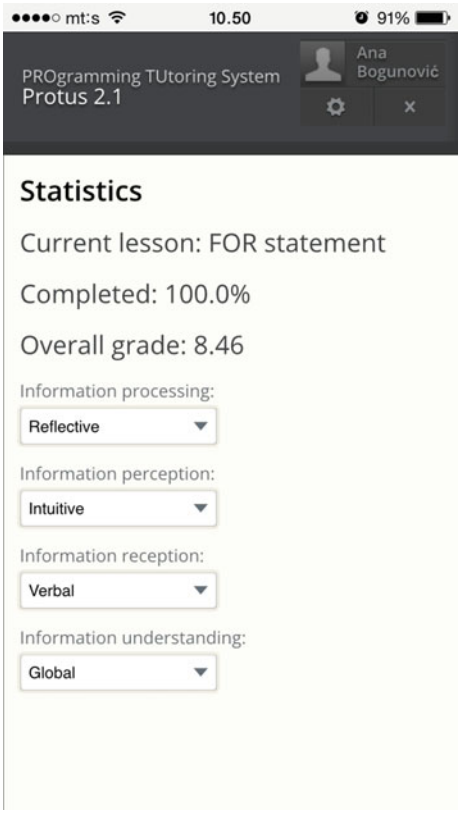
5 Application of the Mobile Prototype of Protus 2.1

We have been performed an experiment of using Protus 2.1 for the delivery of adaptive learning activities via mobile devices. We evaluated the responsiveness of the application by its deploying onto various mobile devices with different screen sizes using various networks with a group of 26 students. All students have previously used the same application on desktop computers. The intention was to investigate students opinions on the mobile version of the system.

Students explored Protus 2.1 independently but they followed the learning path proposed by the teacher, in order to test all pages and functionalities. Students used devices they owned, on different platforms (Apple iOS, Google Android and Microsoft's Windows), with different screen sizes (from 3.5 in to 7.9 in) using various connectivity options (3 G, 4 G, EDGE, Wi-Fi). Student were expected to occasionally change the method of access (via different networks).

They were stimulated to test the Protus 2.1 over mobile device and reflect on their impressions related to its use, speed of execution and responsiveness of the pages they visited and discover possible problems. After that, a brief survey has

Fig. 5 *Statistics* Page



been conducted. Students are expected to provide estimates of the extent to which they agree with the statements in the questionnaire (using 1 to 5 scale, 1—do not agree, 5—fully agree) (Table 1).

The test results showed that mobile devices have not decreased the overall functionality. Students highly assesses the user interface display on mobile devices. Most of the students noticed the slightly reduced visibility of educational material but all user interface components were displayed properly. They also noted significantly

Table 1 Questionnaire details

No	Assertion	Overall grade
1	User interface elements are properly displayed	4.1
2	Educational material is clearly presented	3.2
3	Execution is slower on mob. devices compared to computers	3.9
4	The application is responsive	4.3
5	Overall satisfaction with the use of the app. over mobile device	4.2

slower execution of the application, but found useful ability to access the system on a variety of devices.

High final score of 3.9, for overall impression on the use of the application over mobile devices, testified that despite some problems (reduced visibility and execution speed) students enjoyed the mobile learning environment.

The second phase of the study was conducted with 51 students from two courses. The goal of this phase was to let the students experience of our mobile e-learning environment but instead of just giving their feedback on our application, we wanted them to give us their perceptions on the potential role of mobile learning in programming area. The students used this system for three weeks to access and discuss the class materials. This was followed by a survey using the same 5-point Likert scale used in the first phase. However, the survey questions were modified to emphasize not just on our implementation of the system but on the use of mobile applications, in general, for programming learning. The results of the second survey are shown in Table 2. The results from the second phase show that the students expect mobile learning system as an effective learning tool or service, making flexible access from anywhere and suitable to use application. Students also perceive an important supplementary role for mobile devices in e-learning and are effective in delivering personalized content. The survey results were also grouped by student agreement and disagreement on the ten questions (see Table 2) of our survey. As shown in Fig. 6 there was strong agreement or agreement on all the ten questions. Students in general support the use of mobile devices in learning and foresee a strong role for these devices in improving flexibility and efficiency of the learning environment. The qualitative comments from the students support the quantitative results. Students liked the convenience, ease-of-use, ability to be reminded, and the mobility factor which allowed them to utilize any dead-time for productive learning activity. But they also disliked the small screen-size, tedious process of typing on phone keypads, and slow connection speeds, response times, lack of pictures and visual stimulation.

Table 2 Results from 2nd survey of 51 students

No	Assertion	Overall grade
1	Protus adds value to e-learning	4.74
2	Protus allows instant access regardless of your location	4.3
3	Protus is useful to supplement to an existing course	3.61
4	Protus is an effective learning aid or assistant for students	4.23
5	Protus is an effective method of providing personalisation	4.75
6	Protus allows to convert any wait time into productive	3.89
7	Protus convenient access to discussions anywhere and anytime	4.44
8	Protus that sends the information via messages may be better	3.50
9	Protus also allows access to information from the website	4.15
10	Protus can be used as a supplemental tool for any existing course	4.75

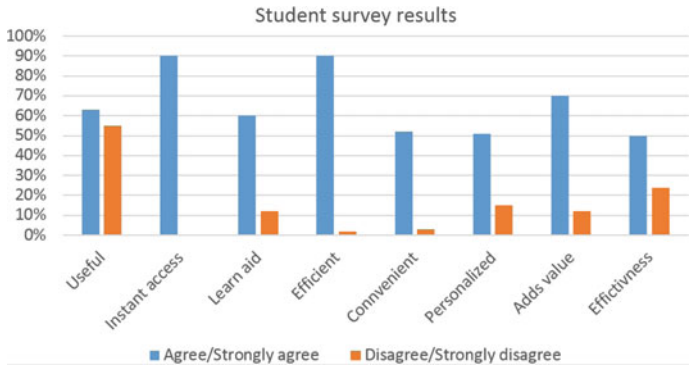


Fig. 6 Student survey agreement/disagreement analysis

The evaluation study was successful because it gave us some feedback on what the students think about our e-learning system, helped us determine whether the students find the flexibility of mobile devices useful for learning and their opinion on the role of m-learning in education. Our study confirms the findings of previous research discussed earlier. Mobile device usage is bound to increase in the future and they will have a significant impact on the quality of student learning.

6 Conclusion

Mobile devices as an emerging technology possess the huge potential to support strategies that exploit individual learners context. The widespread use of mobile technology, supported with the availability of efficient mobile broadband connections, offers a unique opportunity to develop innovative e-learning applications.

Variety of learning platforms, standardisation of content, use of Semantic web technologies, enables semantic search engines to effectively retrieve and present educational material and provide advanced services to learners.

This paper presented the implementation of mobile version of Protus 2.1 system in order to provide its functionalities to mobile users. The framework, in conjunction with the Semantic web technologies, will offers new opportunities for mobile learning, not limited to different hardware specifications, but enhanced with portability.

Given SWRL examples are useful but also complicated, as they require a fairly complex mapping of learning resources to presentational and layout metadata. They place a burden on the authors of materials. For the future work, we plan to simplify whole semantic structure and to direct an attention on measuring the influence of specific classes on performance of the application.

We hope that this research will reveal that computer based instruction can still be effective in situations where the novelty of mobile technologies distracts the learners from the task.

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