Adaptive Heterogeneous Learning System

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Abstract

The iSign project started in 2000 as a web-based laboratory setting for students of electrical engineering. In the meantime it has broadened into a heterogeneous learning environment offering learning material, adaptive user settings and access to a simulation tool. All these offerings can be accessed via web and wireless by different clients, such as PCs, PDAs and mobile phones.

User adaptive systems offer unique and personalised environment for every learner and therefore are a very important aspect of modern e-learning systems. The iSign project aims to personalise the content structure based on the learner's behaviour, content pattern, policies, and system environment.

The second aspect of the recent research and development within this project is the generation of suitable content and presentation for different clients. This generation is based additionally on the user preferences in order to obtain the desirable presentation for a given device.

New, valuable features are added to the mobile application, empowering the user not only to control the simulation process with his mobile device but also to input data, view the simulation's output and evaluate the results.

Experiences with students have helped to improve functionality and look-and-feel whilst using the iSign system. Our goal is to provide unconstrained, continuous and personalised access to the laboratory settings and learning material everywhere and at anytime with different devices.

Keywords: adaptive systems, content generation, mobile learning

1 Introduction

Today's network landscape consists of quite different network technologies, wide range of end-devices with large scale of capabilities and power, and immense quantity of information and data represented in different formats. A lot of efforts are being done in order to establish open, scalable and seamless integration of various technologies and content presentation for different devices. This research is an attempt to bring user-centric, personalised and adaptive user experience to the university student when performing his learning tasks.

In this perspective, our research focus on recognition of user/student preferences, needs and habits in order to design and demonstrate a solution which will make underlying technology transparent for the student and allow him to concentrate only on learning in the time he wants, on the end-device he chooses and in the format he prefers. In order to achieve that, we first had to gain an overview of the existing technologies, standards and available solutions. Second, we had to "get to know" our user/student in order to be able to develop reliable and close-to-reality learners model. At the end, we had to map those requirements and get the idea of the possible solutions.

The paper starts with introduction of the iSign project and our motivation to improve student experience when using iSign platform. It demonstrates the possible scenario of the system use. The chapter 3 gives an overview of the challenges we have faced when designing architecture of the system aimed to support different end-devices and different users. Chapter 4 goes more in detail in the adaptive aspect of the system. Conclusion and future work are covered in the last chapter.

2 Motivation

In year 2000, the web application for accessing laboratory settings iSign (iSign) replaced the input of data and control of simulation tool over console. The students were not anymore obliged to come to the lab and do their exercises with unfriendly UNIX console but were able do their task from any PC connected to the web, using intuitive and rich user interface that offered much more functionality. Since then a lot of improvements of the system were done: 2D visualization of the simulation results, learning content, 3D representation of the structure and calculated fields, SMS notification of the finished simulations etc. (Christ et al. 2004). Finally, since year 2003 the system has been extended to support control of the simulation over mobile devices (Mitic 2003, Mitic et al. 2004). Latter led to the burst of ideas to improve and support not only different end-devices, that student would like to use, but also to offer more personalised use of the system that would adapt to user preferences and goals.

2.1 Scenario

The following scenario of the foreseen use has been designed in order to capture the nature of learners' interaction with the system. The scenario is supposed to show the most relevant challenges in designing a system, concerning device variety, content selection and presentation, user modelling, user interface design as well as use of available technologies.

> *In this scenario, a student David is at home preparing to go to the University when he receives a SMS message on his mobile phone where he is reminded on submission deadline for the lab exercise. Message is also sent to other members of his group, Mary and Peter. The SMS message contains a URL link to the Web site where the detailed description of the exercise is provided.*
>
> *On the way David reads the exercise description on the browser of his mobile phone and prepares for the calculation of simulation input using offered online learning material. In order to collaborate with other members of his group he uses SMS to set up the appointment. After arrival he heads to the PC room where he continues his reading session on the same position where he stopped on the mobile phone. Using online access to the learning material and simulation tool he calculates the structure for simulation, enters the input data, proves the structure in the 3D visualisation tool, and starts to simulate given structure. As the simulation takes too long he leaves the PC room and head to student restaurant for lunch. Mary, other member of David's group is also preparing for the lab exercises by reading online learning material. Unlike David, who prefers material with visual representations that proceed from the specific to the general, Mary prefers written and spoken explanations that go from the general to the specific. Both of them learn better with linear, orderly, in small incremental steps material, different from Peter who is a global learner. He learns better with holistic, large leaps material. The learning system adapts the presentation of content upon the user personality.*

During lunch he receives the notification that his simulation is finished and that he could proceed with the second part of the simulation. Additionally he receives the MMS with the graphical representation of his result. As his results seems to be wrong he changes some input values using his mobile phone and starts the simulation again. The received MMS shows that this time results seem to be correct and he starts the second part of the simulation using the application on his mobile phone.

On the way home he receives the notification on his mobile phone that his simulation is completed together with the graphical results with the evaluation curve in which his results are compared with the results expected. Evaluation text is spoken on his mobile phone and he hears an audio report on the result analyses. After arriving home he turns on his PC and finding Mary and Peter online he discusses with them the results and all together prepare the final report for the professor.

The main purpose of the scenario is the extraction of detailed requirements for the architecture of the system. The system discussed in this paper is compound by a combination of two-dimensional adaptive process. The first dimension addresses the different presentation devices and is discussed in the next chapter. The second dimension is concerned with the adapting of the content for the different users learning personalities and is discussed on chapter 4.

3 Support of Diversity

As it is to be seen from the previous scenario student is motivated to use different devices to access the system depending on his location and preferences. Nevertheless, student experience should be the same no matter of device he uses. Change of device should be as easy and transparent as possible. On one hand, the content presentation should automatically change to fit the devices capabilities, and on the other hand, it should benefit from different device functionality. In the next sub chapters different aspects of content creation, personalisation and presentation for different devices are discussed.

3.1 Device Independent Content Formats

The number and variety of devices capable of accessing the web continues to grow. As a result of this increasing diversity the application developers and user interface designers face number of challenges in attempt to support all different devices and capabilities (W3C, 2005). On the other hand, new devices offer additional functionality, e.g. mobile devices can offer location information, apart from using conventional display for input and output some devices can use voice, etc. Thus, content creation is directly affected by the need to support many types of target device.

The first step is to make clear separation between presentation and logic. The second is to keep the content in the format best suitable to be presented on different devices. It may be necessary to create different versions of content, particularly images, audio and other rich media, to cater for the different capabilities of various devices. Creation of alternate forms of content may also be necessary so that material can be delivered to devices that cannot support particular kinds of content (W3C, 2003). Standard solution for this is using XML format. Thus, content can be easily transformed to pure text, HTML or PDF, graphical formats like SVG or speech (VoiceXML). For example, in our scenario student David get a voice notification of his results. This is done by transforming XML into VoiceXML which is then translated with the help of a speech synthesiser (FreeTTS) into speech. This sound file can be streamed (Darwin Streaming Server) to mobile device or send as MMS or WAP-Push message to mobile phones. The voice capabilities of the mobile phone can be also used for user interaction with the system, e.g. control of the simulation.

Our research on this topic led to the conclusion that without a flexible and open platform for content generation that will decrease efforts to support existing and new coming devices and formats, we won't be able to provide such a universal access.

3.2 Personalised Content Presentation

In our system there are two different places where personalisation takes place. One is the content personalisation discussed in chapter 4 and the other the per-user-per-device personalisation. In case of more than one visual presentation available or in case of content being presented with more than one visual presentation on a device, the system has to make a decision. Because the learner has to understand the content an adequate presentation is important and his preferences has to be taken into account. The fact of a user dependent for a device presentation leads to the need that every learner has to be identified by the system. Therefore the user has to login to the system and identify himself. The

information like user name, password and last visited content are stored in the user profile. This information can be use to offer the learner the last visited content the next time he logs in. The learner is able to specify more information in such a way that the system can adapt easier to the learner. The overall goal is to present the learner a homogeneous system or at least to give him such an impression. The possible device capabilities of different end user devices have to be examined to take into account the possible visual presentation of the learning material.

3.3 Device Dependent Presentation

The research resulted in a three device class classification. The high-end devices are personal computers, the medium class are the PDA like devices and the low-end are mobile phones. Each class of devices is handled by a system presentation module which prepares the presentation of the data for the connected device while taking the user profile information as well as the device capabilities into account (see Figure 1). As consequence the learner has three different personalisation profiles in his user profile, for every device class respectively.

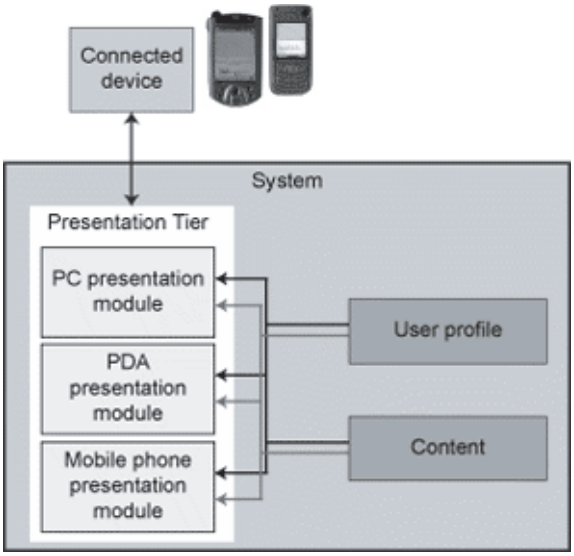

Figure 1: Device presentation modules

The easiest class according content presentation is the high-end class. There is no content visualisation which is unusable for such devices. Different learners may prefer different content presentation and therefore have the impression that a specific content form is unusable for them because they do not like it. Nevertheless all form of presentation can be used which are text, images, animation, video, speech and the combination of all. That is different with the medium and low-end class devices. For example a long text is not usable on a small mobile phone screen. In this case it makes sense to transform the text into speech which can be listened during the travel.

The device dependent presentation is an optimisation process concerning two different aspects which are device capabilities and user dependent information. Out of this information the closest possible content presentation is chosen which is in best case the learners most preferred. Figure 2 and 3 are examples of different device presentation.

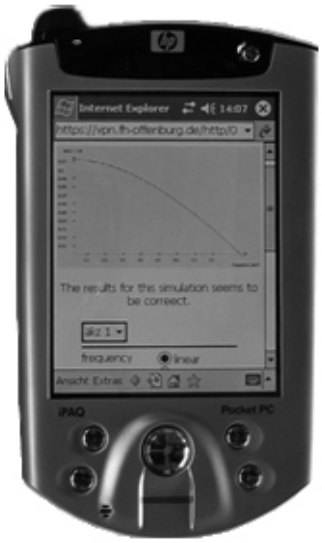

Figure 2: Example presentation on PDA

Figure 3: Example presentation on smart and mobile phone

4 Adaptive Learning Systems

In the scenario described in chapter 2.1 David, Mary and Peter are preparing for a laboratory. There they use the system to lean a collection of concepts. As each of them has a different learning personality and learning goals, the system adapts the content to match with their learning personalities and goals. For doing so, *content nodes* (atomics pieces of content) with common learning characteristics are grouped in clusters. During the user visit the system correlates the user situation and personality with the content clusters. Based on the result of the correlations, the system dynamically structures the *content nodes* with the most appropriated 'models of learning' and suggests the next content to be learned (dos Santos 2004).
The different models of learning influence the navigation flow. These differences are visualised in the Figure 4. There one can see, a linear navigation (PowerPoint approach), a tutorial organization with decision statements and loops, a non-structured navigation (web style), and a hybrid approach.

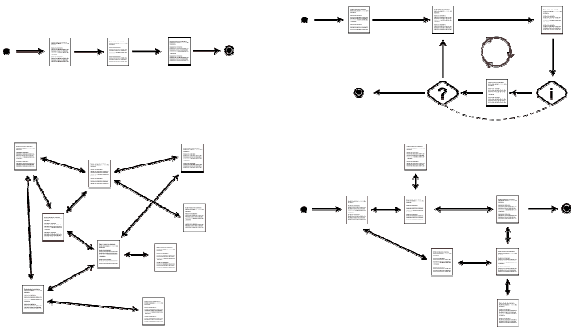

Figure 4: Navigation flow for different learning approach

An adaptive learning system able to carry out this task should switch dynamically from different learning models and content clusters, following the user characteristics and content usage. Such a system should have to own two attributes:

- Flexibility - meaning that the system has a modular structure, supports different models of learning and media types, and has a simple and standard way to store and manage the content.
- Intelligence - meaning that the system provides different environment to different learning targets, has automatic evaluation and grouping of users and content, and is able to recommend a suitable next step for different user situations.

4.1 Content Relationship

For the system to be able to guide the user through the content, it should store the content relationships and paths. This happens with the help of content clustering.

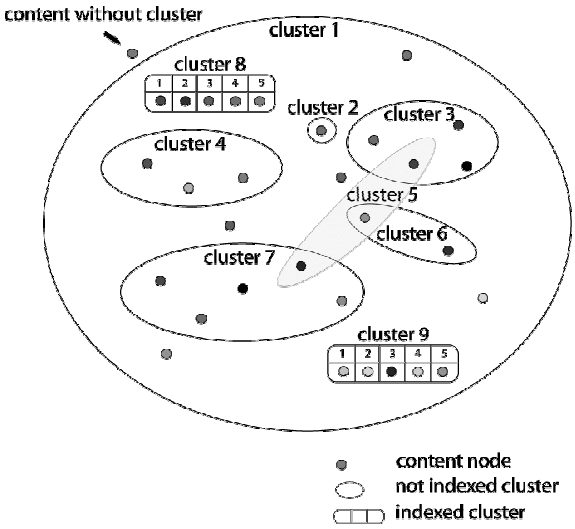

Figure 5: Clusters Structure

Cluster is an entity generated from the *content nodes,* which are in relation to each other. A *cluster* can store *content nodes* and other *clusters*.
Cluster can be generated automatically by the system or manually by the author. E.g.: The system might group a *content node* that holds the introduction for the "Microwave Lab Exercises" with nodes that contains its theoretic concepts, or the system might group two nodes that are from different chapters, but are always used together by the users.
Figure 5 introduces some possible cluster structures. Here several arrangements are represented, their meanings are explained below:

- Small circles - represent content nodes. They can be inside or outside the *cluster*.
- Ellipses – represent not indexed *clusters*.
- Squares with rounded vertex – represent an indexed *cluster*.

Each element of a cluster has a *weight.* The *weight* determines how strong the relationship between the cluster and its elements is. E.g. In a cluster that joins information about "The South America Continent" nodes that describe the whole continent will have stronger weight than nodes that describe specific characteristics of each country like "Brazilian history". A cluster can be indexed or not. Indexed cluster means

that all elements within a cluster have a unique index, due to which it is possible to pick out a specific position. This feature is especially important for an author who wants to set a fixed path.

4.2 Personalisation Processes

The system analyses the user's behaviour, while dealing with specific content and with the system as a whole. It also analyses the vocabulary and navigational structure of the content. User and content patterns are generated based on the result of these analyses. Subsequently those patterns are used to group content and user in clusters, and to determine how strong the connections between users and groups are. Based on the user and content clusters the system performs three types of personalization.

Manual Ruling

Manual ruling is a personalization technique done by the author. He creates rules based on the user profile, demographic region and session history. These rules are used while varying the content.

Collaborative filtering

Typically the collaborative filtering exploits user preferences and/or user rating to correlate his session with the sessions of the others. The result of the correlation is used to predict the content that matches with the user predilection. This kind of task requires data preparation (Mobasher et al. 2000).

Content filtering

The content filtering matches the content visited by the user with the rest of the content that has similarity in theme or in presentation structure. (Mobasher et al. 2000).

5 Conclusion and Future Work

Our research on device independent content generation, personalised user experience and adaptive learning system aims to give a solution for the open learning platform that would support all this aspects.
Thus the system models nowadays teaching scenarios. The student is responsible for his learning progress which will motivate him, but never-the-less he will be restricted if he uses the system in an improper way to learn.
We have been trying to validate our research output by implementing and demonstrating some of its functionality inside of iSign project. However, the platform is still missing some important aspects like security and privacy, possibility of federation with other learning platforms, etc.
The ability to stream sound/voice through the Darwin Streaming Server with the system is available. However voice files are produced in the moment with FreeTTS manually where in future the system has to transform the XML content automatically into VoiceXML which is than used to generate the sound file which can be streamed.
Usability tests, although done till now in an unstructured way, gave first validation and feedback from students. The team members are interviewing students to get an impression where to improve the system. This method works well up to a certain level of complexity which is reached by the system. In this situation structured and well defined usability tests have to be used in order to improve the system further more.
The three modules for the presentation on different devices are realised and are using the partly available XML information of the system.
The adaptive part of the learning system is implemented, however further tests should be performed to define the degree of learning effectiveness of the method. Besides that the present personalisation process is based on rudimentary statistics and should be subject of research. The interface between the adaptive functionalities and the user is one of the keys for the success of the tool and needs to be addressed by further research.

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