Dyslexia Adaptive e-Learning System Based on Multi-Layer Architecture

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Abstract— **The key shortcoming of traditional e-learning systems is that the learning they promote is not adaptive. This paper analyses the e-learning activity of individuals with dyslexia and proposes an innovative design for an e-learning system. This new system is user-centric and interactive based on information about the user's learning preferences. The proposed system design employs a multi-layer architecture, including a presentation layer, an adaption layer, a learning management system layer, an application server layer and a database layer. The learning management system layer contains all the possible systems that provide resources to support the learning process, hence improving the system's reusability. The adaption layer provides the system's adaptive technique functionality, which makes it more intelligent and adaptive – the main objective of this research.**

Keywords—e-learning; Adaptive; Dyslexia; multi-layer

I. INTRODUCTION

Information Communications and Technologies (ICTs) have impacted on the field of education and have undoubtedly affected teaching, learning, and research. It is, for example, now common for e-learning systems to be used in schools to enhance the learning process. Most traditional systems, however, are developed primarily for non-dyslexic users, and either provide the same content to all students or allow students to choose content from massive resources without giving any advice or assistance [1-2]. These two approaches are not reflected in adaptive e-learning systems. Therefore, any new design must be adaptive so that it tailors its learning content to students' needs and preferences.

There are various existing systems that aim to help students with learning disabilities, but most are only means of presenting instructional materials. These systems lack necessary interactivity and encourage learning without any consideration of differences in the abilities and styles of cognition of individual students. They present the same content to different students of different levels and adopt the same learning strategy without concern for the actual needs of individuals. Teaching students in accordance with their individual needs is difficult and demanding without a supportive integrated learning environment. To our knowledge, none of the existing e-learning systems achieves results that sufficiently satisfy students with different types of dyslexia. The need to propose an innovative and original e-learning system arises from these shortcomings.

This paper analyses the adaptive learning approach, centred on different dyslexia types. It then proposes an adaptive e-learning system based on multi-layer architecture and describes a use case scenario that represents users' interaction with the system. Finally, it discusses the different characteristics of the proposed system in comparison with those of a traditional system.

II. ADAPTIVE LEARNING APPROACHES

There are various types of dyslexia and in fact it is hard to categorise dyslexia as a single condition. The question therefore is how to achieve adaptive and interactive learning for different learners with dyslexia. The focus should not be on correlating one technology to one disability, but instead on identifying different pedagogical needs, such as help with reading and writing, and then on trying to meet those different needs in the whole range of ways that are available. Students with dyslexia typically cannot produce written work as quickly as other students and are likely to make more spelling errors even in word-processed work. After analysing the learning process and the different dyslexia types in [3], the adaptive learning approach should include the following aspects:

1) *Adaptive presentation:* In designing an e-learning system, the materials must be presented according to strategies that will enable the students to process them efficiently. Information on the e-learning system should be organised and presented in small paragraphs, which facilitate brain processing, because dyslexics have more limited capacity in their working memory. Miller [4] argues that information in the classroom should be grouped into meaningful sequences to help people with poor short-term memory. Therefore, different interfaces with various kinds of adaptive information must be provided to different users according to their needs and preferences.

2) *Adaptive learning resources:* Referring to dual-coding theory [5], information received in several modes, such as both textually and visually, will be processed better than information presented in a single mode, such as text alone. This would help individuals with dyslexia such as 'visuospatial difficulties'. Learning resources such as multimedia courseware, assignments and quizzes are filtered to the learners based on the specific characteristics of their adaption filter rules. Teachers can recommend various resources to different students according to their preferences and type of dyslexia. Each student's learning

content is different. This embodies the meaning of adaptive learning resources.

3) *Adaptive learning activities:* Different learning activities should be offered to accommodate different learning styles. Catering to a learner's style will help the user to overcome the unsuccessful process commonly observed in system operations that are designed for a specific group of users.

4) *Adaptive guidance:* The system stores a learning log of learners' activity, which can be analysed in order to provide different adaptive guidance and recommendations to every learner.

5) *Adaptive communications:* Group collaborative learning is an important mode of learning. It increases the understanding of diverse perspectives. Adaptive communication means that the system suggests different groups of users according to learners' dyslexia types and preferences.

III. MULTI-LAYER SYSTEM ARCHITECTURE

System architecture is a conceptual description of the design, content, structure, behaviour, and other aspects of a system [6]. The system architecture consists of system components, the properties of those components, and human interaction with them. It also represents the relationships between them and how they work together to implement the overall system. Jaakkola and Thalheim [6] state that system architecture supports reasoning about the structures of the system. The system architecture for the proposed system is shown in Fig. 1.

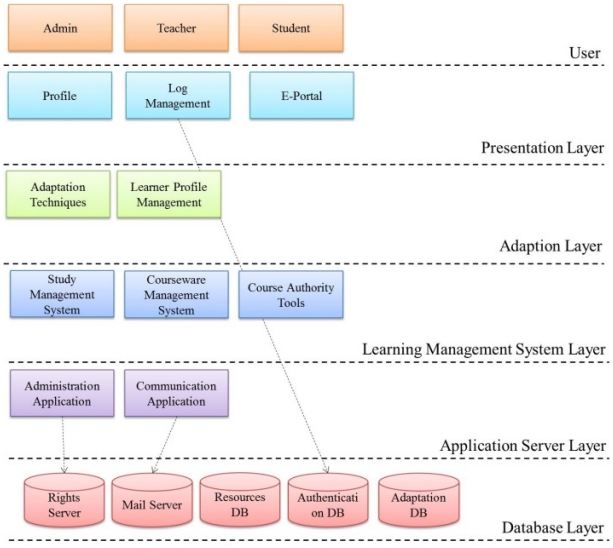

Fig. 1. The proposed system's multi-layer architecture.

The clear structure of the system architecture has many advantages. Multilayer application architecture provides a model by which developers can create flexible and reusable applications. By segregating an application into layers, developers acquire the option of modifying or adding a specific layer, instead of reworking the entire application [7]. Each layer has clear responsibilities and is easy to expand. If new functions are developed, these efforts will be added to a specific layer, and there will not need to be additional efforts on the other layers. In terms of development of the application, a multi-layered approach allows newly added functions to be changed quickly. Moreover, system layers can be reused in other application systems [8]. Application systems are traditionally achieved using C/S (Client/Server) or B/S (Browser/Server) basic two-layer or three-layer architectures. Client server applications follow two-tier architecture, but web server applications follow three-tier or n-tier architecture. Compared with the C/S structure, the B/S structure has advantages in terms of openness, ease of integrated and the ability to uninstall client software. However, the basic B/S three-layer architecture can be improved to serve software reusability [8, 9]. Therefore, the system architecture is designed based on B/S multi-layer architecture.

The users who are dealing with the system are divided into three different types: student, teacher, and developer. It can be seen from Fig. l that the proposed system consists of five layers, with specific roles for each layer.

A. Presentation Layer

The presentation layer is the top layer, which deals directly with the user and offers an accessible and user-friendly interface. This layer relates to the code that is responsible for implementing the user interface. One of the responsibilities of this layer is creating a profile for each user; this is to ensure that the system will be adaptive in presentation and navigation to the characteristics of different students. The system will remember the preferences of each user, once he or she logs in, with the help of the 'Log Management'. This layer is responsible for acquiring the identity of the user and transferring the acquired information to the database layer for authentication.

B. Adaption Layer

The adaption layer creates different presentations, specified by the presentation layer, based on the combination of items from the other modules and the 'Learner Profile Management'.

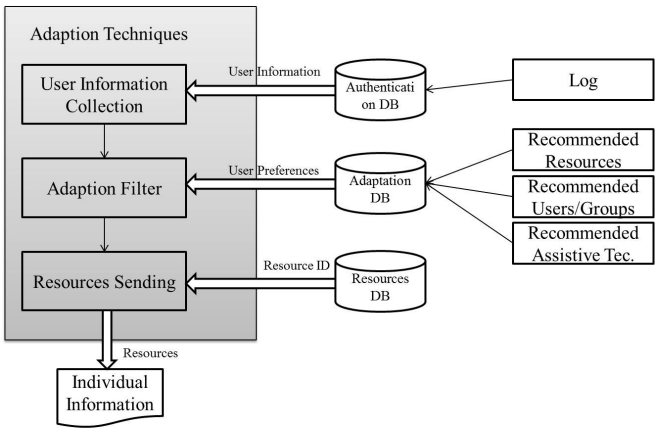

Fig. 2. Adaption Technique Architecture

The adaption technique Architecture is shown above in Fig. 2. It comprises three sub-modules: user information collection, adaption filtering, and resource (or information) sending. The statuses of all the students are stored in the authentication

database (DB) through the log management. The adaption DB preserves a variety of learning preferences, including records of resources recommended or prescribed by teachers (or the system) and other students. The adaption technique process is as follows:

- First, the user information collection module collects a variety of learning status information;
- Second, based on user information, the adaption filtering module reads the learning preferences, such as the records recommended by teachers, assistive technologies recommended by the system, and groups, to get a personalised resource ID;
- Third, the resource sending module chooses the resource from the library using the resource ID and sends it to the user.

The process shows that the filter can provide personalised information to different users by intelligently and automatically filtering information from the system's massive resources. Once the user logs in successfully to the system, he or she will be asked to give some information in order to personalise their use of the system. These results of this process will be stored in the 'Learner Profile Management'. This profile stores any of the user's special requirements in order to customise the system and is reusable by any other Learning Management System. By using the information in the 'Learner Profile Management', the system can group users according to their system preferences. For example, 'themes' will have tag values in the database that represent each kind of dyslexic difficulty so that they can be made visible to the user.

C. Learning Management System Layer

This layer is the essence of the teaching process. The Learning Management System layer offers a set of tools that allows courses, lessons and teaching materials to be managed. The Learning Management System layer allows courses to be previewed and published to the students. The author has to be aware of the required needs and preferences of learners during each step of the course creation, from analysis to evaluation.

D. Application Server Layer

The application server is the middleman between browser-based front-ends (the first three layers) and the back-end database layer. The capabilities and permissions for each user are handled by 'Administration Application'. This layer provides communication, such as by email server. It supports both synchronous and asynchronous communication.

E. Database Layer

The database is considered as one of the proposed system layers. It stores data, including the database of learning resources, authentication, mail server, and right server. The adaption DB records the learning status of each student, and stores the main data used to filter the personalised information of the user.

IV. USE CASE

Mrs. X works in a large university. Once a student is accepted for enrolment, it is her job to set up their initial account in the Learning Management System. She uses a copy of a form submitted by the student (in this case, 'Mr. Y') that contains basic demographic information as well as some indication of disability, if any.

Mrs. X logs into the system using her user name and password. Mrs. X is recognised as a user with administration privileges and the 'Administration Application' is displayed. Mrs. X does not have any disabilities, but prefers to view larger text than is typical for these applications.

From the 'Administration Application', Mrs. X selects the Create New User option. This displays a form prompting her to enter a new user name and other demographic information. Mrs. X enters Mr. Y's information from the paper copy provided by him. The form is submitted and Mr. Y is created as a new user in the Learning Management System. A password is automatically created for Mr. Y, which Mrs. X notes.

From the provided information, Mrs. X sees that Mr. Y is dyslexic. She then invokes the Create Accessibility Preferences function from the 'Learner Profile Management'. This function prompts her for Mr. Y's user name and password, which she supplies. Mrs. X has the choice at this point of creating a detailed set of accessibility preferences for Mr. Y or of using one of the default templates that the system provides. Since she doesn't have much information about Mr. Y's preferences or type of dyslexia, she selects a template which is a text reader friendly style. Once he receives his password information, Mr. Y can alter his settings to reflect his preferences anytime he logs into the system. Mr. Y can set up his preferences by answering a series of functional questions. The resulting preferences are stored in the 'Learner Profile Management' as specifications.

Mr. Y has received his user name and password information via email. Mr. Y logs into the system using his user name and password. Mr. Y is recognised as a user with student privileges and the 'Administration Application' is displayed. Mr. Y is a student with dyslexia, and Mrs. X selected a text reader friendly style template for him. The system invokes the Create Accessibility Preferences function from the 'Learner Profile Management'. This function prompts a series of functional questions regarding the student's disability type and preferences in text reader friendly style. Mr. Y answers the questions concerning his dyslexic difficulties (in his case, reading) to help the system to adjust to his needs and preferences. Once Mr. Y answers all the questions, the system will suggests a couple of themes, styles and assistive technologies. The resulting preferences are stored in the 'Learner Profile Management' as specifications.

A. Admin - Create New User

The following steps explain the process of creating a new user profile by the system's admin (see Fig. 3).

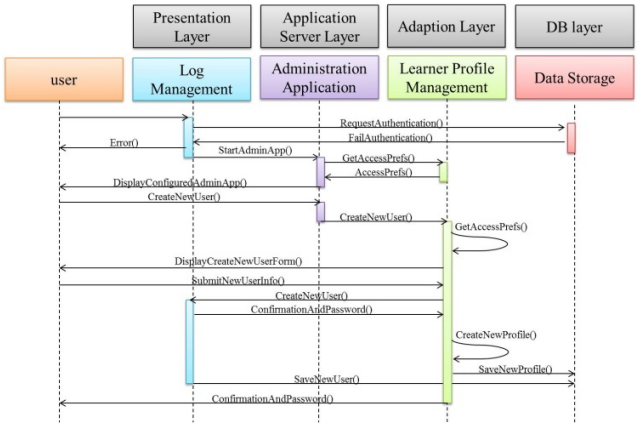

Fig. 3. A UML diagram illustrating the creation of a new user.

1) User logs onto the system.
2) Verify that user is an administrator with appropriate access levels.
3) 'Administration Application' requests 'Learner Profile Management' preferences - user has larger type preferences.
4) Admin configures for larger type.
5) 'Administration Application' is displayed.
6) Access to Create New User function is initiated.
7) Create New User form is adjusted to display in larger type.
8) Create New User form is delivered to user.
9) Information on the new student is entered.
10) Form is submitted
11) New profile is created for the student.

B. Admin - Add Accessibility Profile Template

This case focuses on the admin creating the initial accessibility needs for the user after creating his/her profile (see Fig. 4).

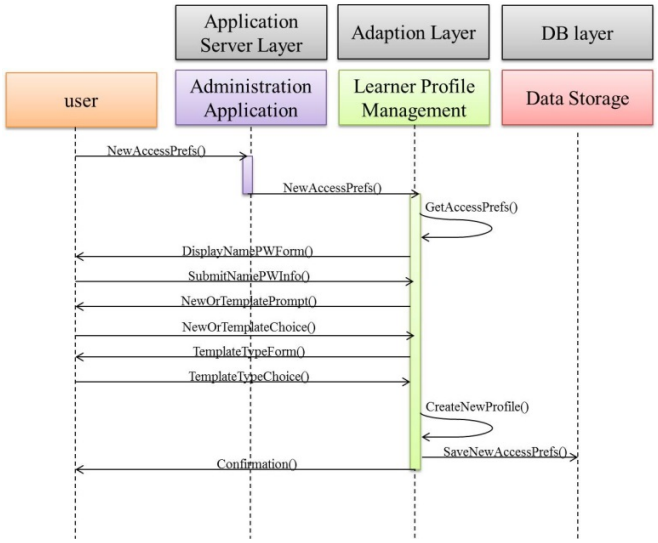

Fig. 4. A UML diagram illustrating the use of a set of pre-defined accessibility.

12) Access to Create Accessibility Preferences is initiated.
13) Prompt for student name and password is formatted for larger type.
14) Prompt for student name and password is displayed.
15) Prompt for Create New Accessibility Preference or User Template is formatted for larger type.
16) Prompt for New or Template is displayed.
17) Select Template.
18) Form for selecting template type is formatted for larger type.
19) Form to select template type is displayed.
20) Select template type.
21) Default accessibility preferences are added to the student profile based on the template selected.

C. Student - Add Accessibility Profile Preferences

This scenario describes how a user would create their own learner profile and modify it to meet their particular accessibility needs (see Fig. 5).

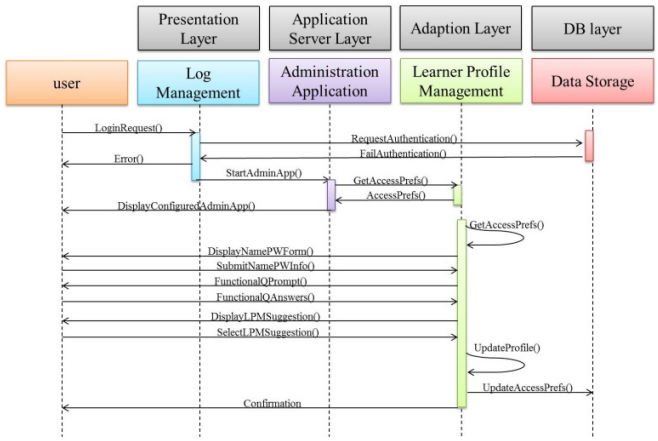

Fig. 5. A UML diagram illustrating the updating of a set accessibility by a student

22) User logs onto the system.
23) Verify that user is a student with appropriate access levels.
24) 'Administration Application' requests 'Learner Profile Management' preferences – text reader friendly style.
25) System invokes the Create Accessibility Preferences function.
26) Prompt for the student's name and password is in text reader friendly style.
27) Prompt for the student's name and password is displayed.
28) Prompt for a series of functional questions in text reader friendly style.
29) Student answers the questions.
30) 'Learner Profile Management' suggests a series of themes and assistive technologies.
31) Select preferences.

32) Default accessibility preferences are added to the student's profile.

V. PROPOSED SYSTEM CHARACTERISTICS

Compared with the traditional system, this new system has obvious personal characteristics as follows:

1) It is user-centric, rather than resource-centric. The system is based on students, teachers, and administrators receiving personalised information. Each user has different capabilities and permissions to use the system.

2) The system records the user's learning status, which is the basis of the filtering to provide personalised information. Tradditional systems rarely record learning logs, without which it is difficult to provide target-personalised information.

3) To enhance user interaction and collaborative learning, the system suggests groups based on the learners' preferences and needs.

4) In most existing e-learning systems, commonly discussed usability features are included, but other features such as conventions, user diversity, and customisations are not addressed. This is because that most of the common systems are developed for just one group of people (i.e. the 'non-disabled'), and therefore eventually tend to fail in terms of accessibility and usability for different group of people.

5) In order to improve the user experience and increase the ease of use and usefulness of the system, the system recommends preferences and assistive technologies to the user that adjust to his/her individual needs. It thereby increases the intention and ability of user to use the system.

6) The system can be adapted to cater for any users' disabilities or needs.

VI. CONCLUSION AND FUTURE WORK

This paper proposes an e-learning system for students with dyslexia based on five adaptive learning approaches. The developed system is based on B/S multi-layer architecture. The five system layers are: presentation, adaption, learning management system, application server and database layer. The adaptation techniques filter in the proposed system is innovative and has advantages over traditional e-learning systems. User and expert evaluations are being conducted to validate the components of the proposed system. Such evaluation activities will be discussed in detail in future papers.

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