



Virtual Learning Environment for Visually Impaired

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April 8, 2020

VIRTUAL LEARNING ENVIRONMENT FOR VISUALLY IMPAIRED

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Abstract

Virtual Learning Environments (VLE) is web-based platform used for teaching and learning. Though there exist many VLE platforms which have been developed for learners and instructors, their accessibility to a visually impaired student remains a problem. Many visually impaired persons especially students, do not participate fully in courses delivery and are therefore disadvantaged. After careful analysis of the current state of the accessibility of VLEs, this paper proposed a solution as a way to also further the adoption of Internet of Things (IOT) in learning. The system analysis and design, followed the object-oriented analysis and design approach. The solution provided enhancements to accessibility issues; content and navigation that confront visually impaired in its implemented web-base software. Only the key features for assisting the visually impaired, based on the propositions are presented in this paper. The system implemented loosely coupled modules for course management and accessibility. It provides a text-to-speech integration and keyboard shortcuts to enhance reading.

Keywords: Virtual Learning Environment, Web Accessibility, Visual Impairment, Course Management, E-learning.

1.0 Introduction

Virtual Learning Environments (VLE) refers to the computer dependent tutoring in which learners and tutors participate in a variety of online interactions which give rise to learning [1]. VLEs are web-based platforms used as tools of teaching and learning. They may be used independently or blended with traditional classroom method of learning. They can also be used for other purposes such as training of staff by organizations or government. These platforms can be free and open source (e.g. Moodle) or paid (e.g. Blackboard) [2, 3].

VLE is synonymous to Learning Management Systems (LMS), Online Learning Environments (OLE) and Course Management Systems (CMS) [4]. Moodle, ILIAS, Atutor, to mention but a few are open source projects on e-Learning. These systems offer the facilities for distance learning, self-learning, course management, communication and collaboration between teachers and students, course or learning material delivery, announcements and assessments to students [4]. They also serve as repository for course material and offer teachers and students the ability to teach or learn from anywhere and at any time. However, accessibility of VLEs to visually impaired students has been a serious challenge since the advent of computer aided learning.

According to [5], visual impairment covers a wide variety of conditions, some start from birth, others may occur by mid-life crisis such as accident, disease / infection of the eye or gradual deterioration of sight. Visual impairments include low vision and blindness. Low vision refers to loss of visual acuity while retaining some vision. This may be evident in people suffering from near or far sightedness and other ocular conditions that prevent clear sight.

Today, electronic media such as documents, audio and video files have made it so much easier to access learning materials for students with visual impairment. Lecture notes in electronic form, and especially if made available in advance of classes have also proved to be

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quite beneficial [6]. However, the accessibility of the VLE has been a major issue for visually impaired people [5, 6]. Hence the reason for the development of this enhanced VLE application to provide some relief to these group of people.

2.0 Related Work

2.1 Concepts

Concepts such as Computer Aided Learning (CAL), Web Real-Time Communication (WebRTC) and Voice Over Internet Protocol (VOIP) and Speech Synthesis (TTS) have been explored in this section, in order to get a definitive background for this work.

2.1.1 Computer Aided Learning (CAL)

CAL is an educational environment where a computer software package is used to assist the user in learning a specific subject. This concept has been around since the 1970s (*eg "Computer assisted instruction, testing and guidance" edited by Wayne H. Holtzman in 1970*). In the mid-1980s till 1990s, CAL refers to the development of either a software or software suite to replace the traditional teaching methods. Since then, CAL has been progressively more used to describe the use of technology in teaching [7]. CAL is used within two main concepts namely:

- CAL as Computer Based Learning (CBL) and
- CAL as Integrative Technology.

CAL is synonymous with Computer Assisted Instruction (CAI); it is an automated teaching technique that uses a computer to present the learner with an educational program through an interactive computer process [8]. CAL has been used due its several advantages in comparison to the traditional methods. The advantages include:

- easy access to the full content of courses through web pages,
- no access limits,

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- as well as easy and speedy update to content

CAL also refers to an integrative approach of instructional methods; a program of some sort that comprises an overall learning approach, which in itself is an aggregation of other teaching methods, (e.g. the lecture, tutorials, text books etc.).

2.1.2 WebRTC and VoIP

Web Real-Time Communication (WebRTC) is an Application Programming Interface (API) created and maintained by World Wide Web Consortium (W3C). Simply put, it is intermediary software that allows application programs to communicate and share information with each other. WebRTC is used to enable browser-to-browser voice calling apps, video chat and file sharing without plug-in. WebRTC is an augmentation of VoIP to the program world. Since it does not include any signaling protocol, thus, by integrating a signaling protocol, such as web socket, into WebRTC, a developer can create a full VoIP client. [9].

Voice over Internet Protocol commonly called VoIP is the transmission of voice and video data, e.g. in video conferencing, over an IP based network. It makes use of packet switched network and thus should be used over connectionless network. Due to the fact that it uses a connectionless network, it also uses the unsecured User Datagram Protocol (UDP) and does not require any handshake between communicating devices. This makes it viable for transmitting video and audio signal. VoIP has been used as a replacement to the Public Switch Telephone Network (PSTN) which uses circuit switched network. VoIP uses a shared network for the transmission of both voice and signal. It has numerous benefits such as internet conferencing, personal IP calls, instant messaging, and cheaper call rate [10].

The main benefit of VoIP over the conventional form of communication (PSTN) is that VoIP sends packets through packet switched based network in such a way that voice data packets may take the best path from source to destination resulting in low cost. In contrast, PSTN is a

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circuit-based switch technology that requires dedicated line for telecommunications services which drastically increases the cost of communication due to cost of hardware [11]. VoIP was used in this work audio/video broadcast of lecturers where students connect to the live broadcast through a provided channel.

2.1.3 Speech synthesis

In theory, Speech synthesis means any kind of synthetization of speech. For example, it can be the process in which a speech decoder generates the speech signal based on the parameters it has received through the transmission line, or it can be a procedure performed by a computer to estimate some kind of a presentation of the speech signal given a text input [12]. In this project, we focused on text-to-speech synthesis. Text-to-speech (TTS) synthesis technology gives machines the ability to convert arbitrary text into audible speech, with the goal of being able to provide textual information to people via voice messages [13]. Speech synthesis has been applied in delivering answers to the customers as in customer care robots, listening to the messages and news instead of reading them, and using hands-free functions through a voice interface in a car. It's important to the visually impaired and to those who have lost their ability to speak.

Web speech synthesis was used in this work. There is already a number of Application Programming Interfaces (APIs) and libraries available to web developers for the text to speech synthesis. The "Web Speech API" from Google was used in this project. It performs voice recognition (speech to text) and speech synthesis (text to speech) in JavaScript, it converted text to speech so as to enable visually impaired users effectively use the software.

It was chosen out of other available alternatives due to:

- the smooth and fluent way it reads the converted text;
- the robustness of customizing options for voice, pitch, speed;
- naturalness of the spoken text;

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- the fact the it is cross browser compatible and
- its code is still being maintained.

2.2 Accessibility of VLEs

Virtual Learning Environment (VLE) is not a fresh concept as its use has persisted for over a decade. VLEs can encourage deeper learning, which is social, active, contextual, engaging and student-owned, as well as develop lifelong learning skills. Nevertheless, their success depends on the teachers, who should choose the appropriate features and adapt them to fit their pedagogy and teaching style [4].

There is clear indication that there is a potential in using a VLE to provide learners with an opportunity for autonomous learning, however, the realization of this potential depends on several factors which [4] recapitulates as: the type of activity used, the amount of teacher support, the learning situation and students' perceptions.

Blind students necessarily need to rely on screen readers to access electronic media [6] while students with low vision can use specific customization options (like changing font size or font face or other add-on software which can enlarge sections of a page) in addition to optical aids; these features improve accessibility on a wide variety of software applications, including some with graphic interfaces.

Some of the challenges faced by visually impaired students according to [6], can be alleviated by ensuring the institution's VLE is accessible for screen reader users; any VLEs that rely so much on visual multimedia cannot be easily used by blind students because screen reading facilities available do not perform so well with graphics-intensive screens.

Web accessibility means that websites, web-based tools and technologies are designed and developed so that people with disabilities can use them. More specifically, people can: perceive, understand, navigate, and interact with the Web [14]. Improved accessibility also helps people without disabilities to access software and websites better.

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Though there exist QWERTY keyboards, embossed and engraved keyboards, braille digital displays and braille typewriters which are useful in creating braille documents for braille users are useful for visual impaired persons, [15] observed that students or in general learners with visual impairment have a wide range of needs due to the large spectrum visual impairment covers, and highlighted some tools and methods to solve different accessibility needs to include: screen reading software, screen enlargement or magnifier software, movable menu and keyboard driven support to help them access all the functionalities. These suggestions have informed the choice of support features of this project.

In 2009, [2] reviewed available open source and commercial learning management systems and platforms. They identified requirements for an adaptive Learning portal which included ability of information to adapt to student's prior knowledge, learning style, circumstance, interest, among others. Although the results of the research were subjective, it still gives a good reference material to aid in selection of a platform to use.

In the same year 2009, [16] observed that vision impaired students are increasingly being disadvantaged as teaching environments were becoming more vision-centric in presentation of learning material. She observed that web-based content is not accessible to assistive technologies thus making it frustrating to use; she had to build a training environment that was fully accessible to vision impaired persons. The pilot project was conducted to test the effectiveness of numerous accessibility methods in order to ascertain the most effective and incorporate it into the aforementioned training environment. Her study found that vision impaired students performed on par and sometimes better than fully sighted students.

In a conference paper in 2012 [17], define standards for developing e-learning solutions for visually impaired learners, and performed an analytical comparison of 3 distance learning software used in Croatia. The criteria to be met were based on flexibility, visibility and ease of use, they however noted that there were accessibility issues with the systems they used to test and suggested the following guidelines for designing accessible systems:

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- Design should be based on three columns where the center column contains the main content
- Standard keyboard shortcuts should be used to access the menu options
- The content should be presented in an organized manner
- Interface should not use pop up or modal windows and should conform to WCAG 2.0 standards
- Non-textual content should contain descriptive tag
- Auditory feedback is expected
- Data entry should be confirmed before submission

Highlighting the importance of accessible and usable user interface (UI) for e-learning environments [18] stated that UIs most often not always designed to be used effectively by the blind. They made the following suggestions to improve design of tools for personalized learning to include: the design of more accessible interfaces of a Web editing collaborative tool, interacting with a screen reader and a Web system to personalize learning by blind students using audio podcasts and an mp3 player. They also identified some problems with screen readers which tallies with [6].

In 2015, [19] investigated the difficulties in interaction of both blind and deaf users with respect to VLEs, using their master and doctoral students of Postgraduate Program in Inclusive Virtual Learning Environments and emphasized the need for involvement of key stakeholders, i.e. the deaf and the blind, in analysis and design of technological innovations targeted at alleviating difficulties they face in interaction with VLEs.

[20], carried out a study in the development of a virtual classroom to encourage interactive learning, the software was tested at Covenant University. However there was no special consideration for accessibility of the system to visually impaired persons.

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Another study in 2016 by [21] evaluated the effectiveness, efficiency and satisfaction students get from using Learning Management System (LMS) in Malaysia. The outcomes of the research show that students were satisfied with the LMS the student were happy that the LMSs was effective and efficient.

In March 2017, [22] carried out an aggregation of problems experienced by blind and visually impaired students using Moodle VLE into classes. The common problems identified in the study were interface, navigation and content problems.

Although advances have been made recently regarding assistive technologies, The presence of elements of interaction that can be achieved only through pointing devices for example is a barrier for people with visual impairment [23]. They mentioned two important resources that can improve e-learning applications blind people to include adopting and integrating a suitable screen reader and voice recognition systems.

2.3 Summary of Guidelines for Accessible Solutions

Based on the above literature, the following vital features for improving accessibility of VLEs were implemented in our developed system:

- A simple and consistent format for every Webpage;
- All part of the webpage are accessible using only keyboard;
- Most parts of the webpage like navigation and content are speech enabled so as to enable visually impaired users access them;
- WebPages were created to accommodate 3rd party screen reading software to allow some users who are more familiar to other screen reading software to use them.

3.0 The Proposed System

The system is web VLE software which followed guidelines above in its implementation. Some of the features include: reading out an active link (using the tab button press or hovering the mouse over a hyperlink), the voice feedback also trigger both navigation and

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form inputs, the accessibility improvements were loosely coupled, so as to be easily plugged into another existing web-based VLE, course management module, keyboard shortcuts to help improve accessibility for visually impaired, text to speech to provide accessibility for the visually impaired, a real time chats and video broadcast of classes.

3.1 System Design

The software was designed following the iterative software process model. This model allows the design and analysis phases to overlap allowing room for changes which may arise in the course of the design or even implementation. The system enhancement features were implemented using event-driven JavaScript calls to identify when a visually impaired user needs to access a function of the VLE software. The system use a collection of hotkeys and keyboard shortcuts for navigation; mostly based on the tab button which is in line with most modern browsers feature for navigating links and form elements on the page. This is according to [24] which state that tab navigation is enabled by default in most browsers except for safari and firefox for Mac. The software use mouse events like mouseover, mouseout, timeout and hover as well as keyboard key presses (specifically tab button) to read out the pages behind the links. The CSS was used for animation to temporarily zoom sections of the pages when the mouse is idle over them. There is the provision to toggle on and off these improvements for the sake of non-visually impaired users.

3.1.1 Conceptual Design

This section describes the software and identifies the objects interacting in the system. The stakeholders here are the visually-impaired who could be students, lecturers or anybody interested in learning using VLE. Figure 1, shows the entities associations with their cardinalities.

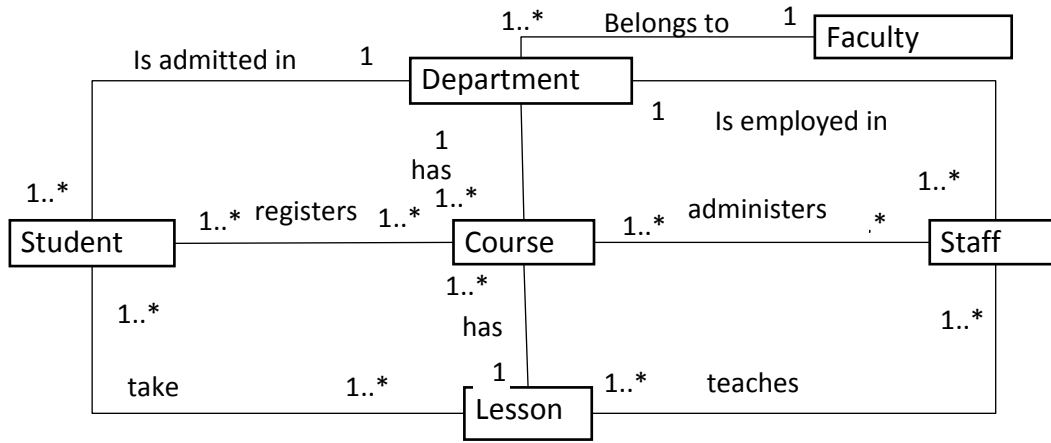


Figure 1: Class diagram showing associations of major system objects

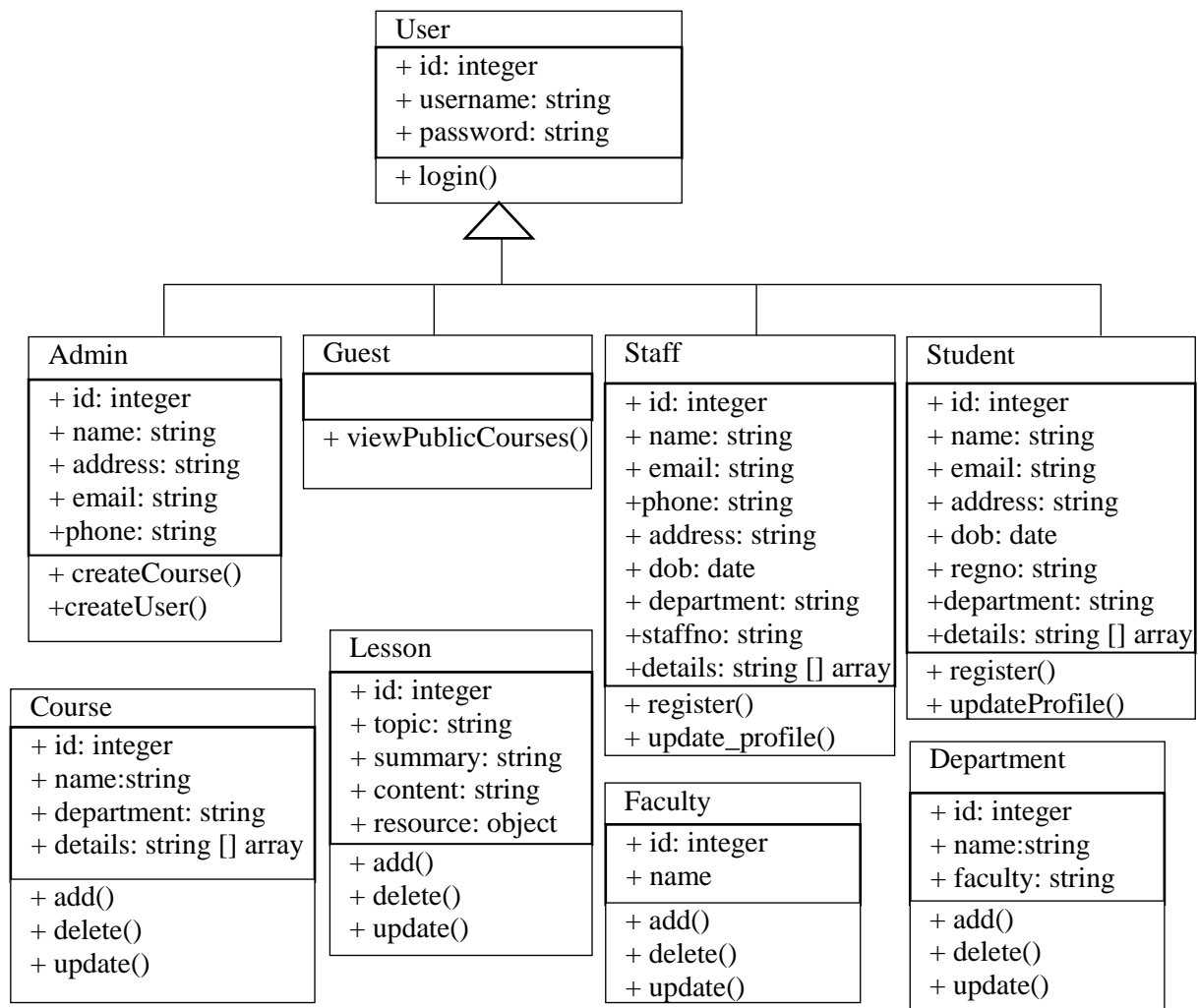


Figure 2: Object class diagram of system

The system entities (users) include students, staff, admin and guest. Student belongs to a department, and each department belongs to a faculty, a student takes courses, while staff administers courses, a course has lessons taken by every student that takes the course.

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The system objects include user, student, admin, staff, course, faculty, department, quiz and result. The object class diagram is summarized in figures 1 and 2.

The accessibility of the system uses in-built Text-to-speech (TTS). The class diagram figure 3 shows the classes for the TTS subsystem. It has a library which controls the rendering and animation of the gif character. This library is extended by the SuperGif class which adds the blinks and controls the mouth movements and speech synchronization. Assistant class converts text to speech using Google's WebSpeech API and the FeedbackMe for rendering the entire setup. The gif speech synchronization was adapted from [25].

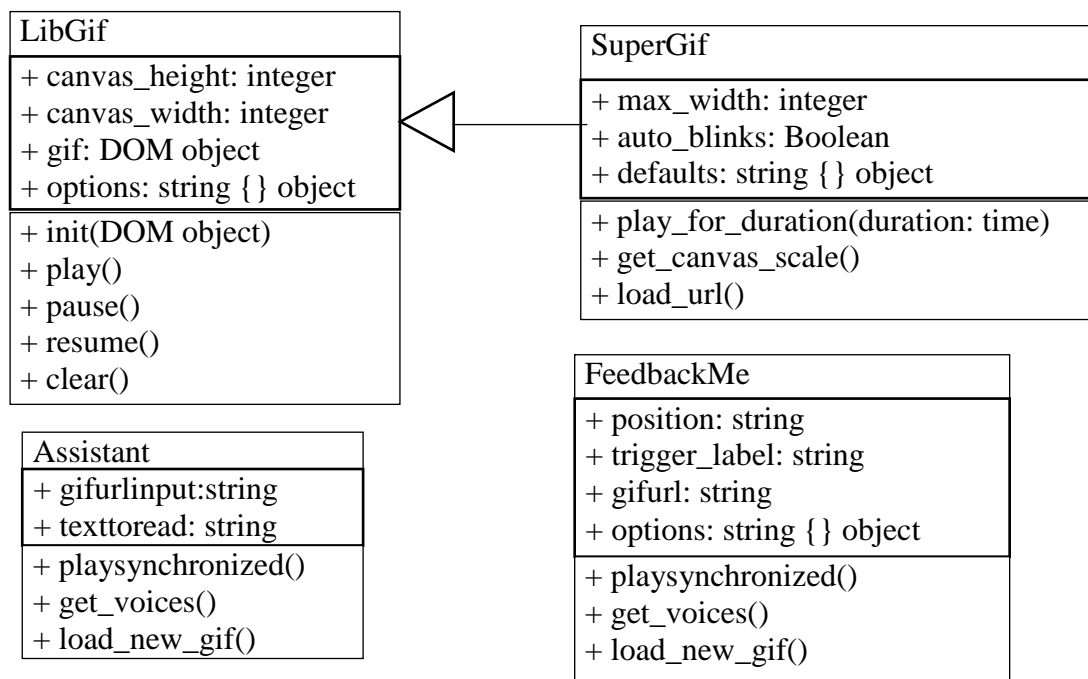


Figure 3: Class Diagram of TTS subsystem

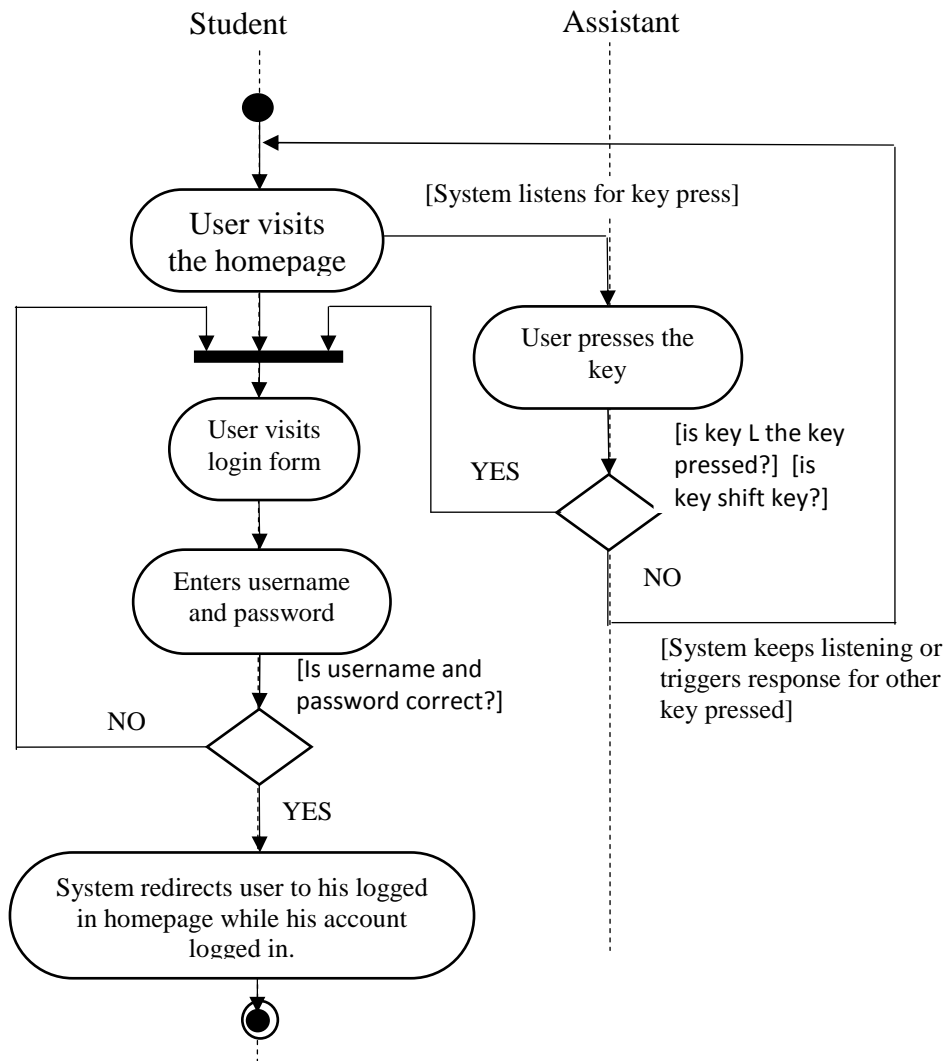


Figure 4: Activity diagram showing how to log in for visually impaired user

The activity diagram figure 4 describes how a user logs into the system.

3.1.2 The System Architecture

The system is 3-tier architecture. The first tier is the presentation layer; it uses web front-end languages HTML, CSS and JavaScript to develop the user interface that runs on any web browser on any operating system.

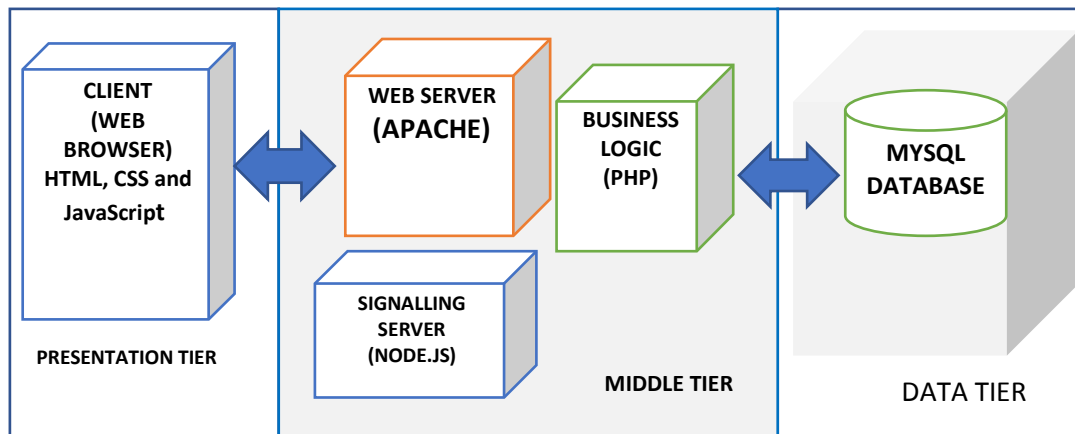


Figure 5: Web software architecture

The processing of requests is controlled by the business logic which is controlled by some server-side scripting PHP, there is also a signaling server used in this project for real time communication. This signaling server is written in node.js and uses socket.io. The last tier is the data tier; the system database server is MYSQL.

3.2 System Implementation

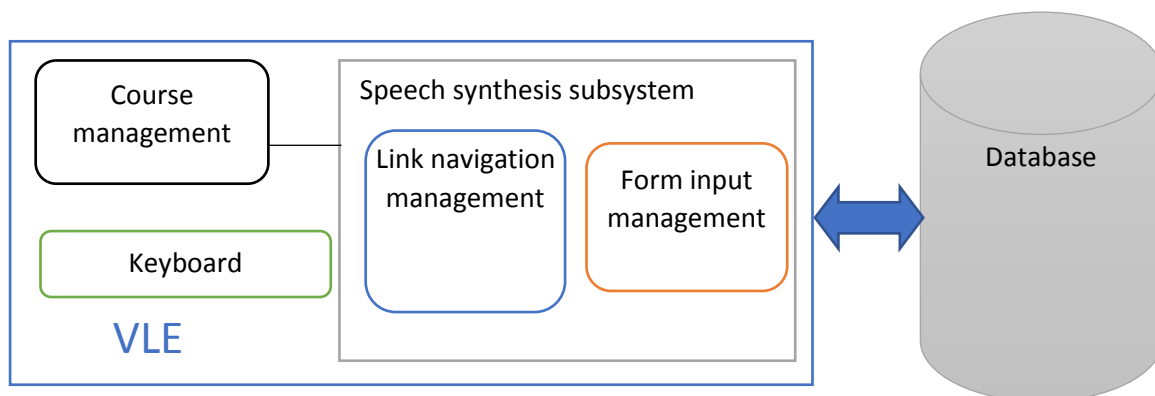


Figure 6: The Implementation Architecture

The software architecture figure 6 shows the modules of the system. The speech synthesis subsystem connects all parts of the system; it has two modules that handle link navigation and form input. The codes for speech were written with JavaScript; ideal because it comprises functional and event-oriented paradigm and the audio segments are triggered by events on the webpage.

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The link navigation module was implemented using the web speech library. The keyboard shortcuts keypress listeners, mouseover, timeout, input box focus and blur events, on tab press navigation were all tested to ensure that they gave desired audio output. Each code to generate and read out an audio output was tested with appropriate link and its trigger event was simulated to ensure it gives expected output. The form control module was also implemented and tested in similar vein.

4.0 Results

A web software with enhance accessibility features was developed. The user use the tab button to navigate to any page, the system reads out the active link or what input box or button is active. The software could also be used by both visually impaired and non-impaired users. A few snapshots of the app is shown in figures 7 and 8.

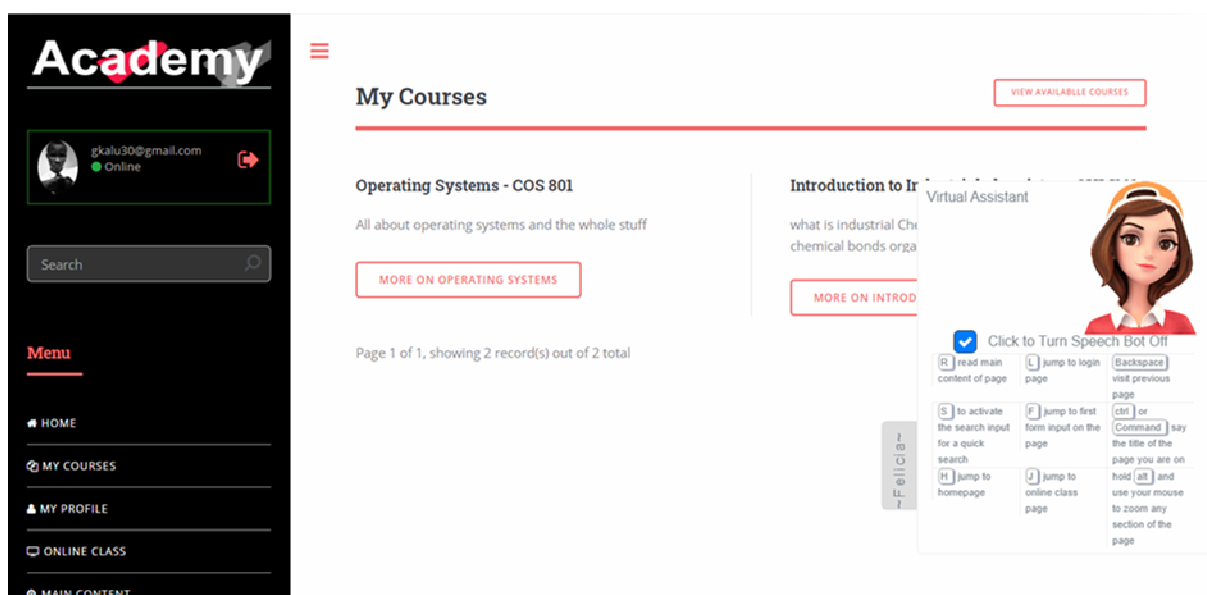


Figure 7: Page showing course registration by the user

The accessibility features can be turned off for those not visually impaired to reduce the intrusive features. In figure 7, the checked box toggles the voice feedback on/off; there is also the collapsible feedback modal at the bottom right corner of the page.

Academy

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Online

Search

Menu

- HOME
- MY COURSES
- MY PROFILE
- ONLINE CLASS
- MAIN CONTENT
- ALL COURSES
- PUBLIC COURSES
- RATE US
- LOG OUT

Notice Board

This is to notify all students that there will be compulsory payment of 1000 naira.

All payments should be made through the school portal, only your remitta number is required for payment confirmation.

Deadlocks

- Deadlock and starvation definitions
- Examples of deadlock
- Conditions for Deadlock
- Resource Allocation Graphs.

[BACK TO COURSE](#)

Lesson Text

A **deadlock** is a situation in which two computer programs sharing the same resource are effectively preventing each other from accessing the resource, resulting in both programs ceasing to function. The earliest computer operating systems ran only one program at a time.

A set of processes or threads is **deadlocked** when each process or thread is waiting for a resource to be freed which is controlled by another process. Here is an **example** of a situation where **deadlock** can occur. ... Both threads are blocked, each is waiting for an event which will never occur.

Four Necessary and Sufficient Conditions for Deadlock

- mutual exclusion. The resources involved must be unshareable; otherwise, the processes would not be prevented from using the resource when necessary.
- hold and wait or partial allocation. ...
- no pre-emption. ...
- resource waiting or circular wait.

A process in operating systems uses different resources and uses resources in following way

- 1) Requests a resource
- 2) Use the resource
- 2) Releases the resource

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Figure 8: The lesson view

Figure 8 shows a section of the course lesson, a user can press key R for the entire contents to be read out. The same key R can be used to pause and resume audio. The system shortcuts some can be seen in figure 7, all can be viewed anytime by clicking the Felicia button at the bottom right corner of every page. The shortcuts include:

- L – takes you to login page
- Backspace – takes you to the previous page (alt + left key is default for this behavior)
- S – activates the search input for a quick search

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- F – activates to first form input on the page
- Ctrl – triggers the software to say the current page title
- H –takes you to homepage
- J –takes you to online class page
- V – to activate input for channel
- Alt + backspace - clears any input field
- Holding Alt and moving the mouse zooms the element over which the mouse is hovered
- R – reads out the contents of the main parts of the page

4.1 Conclusion

This paper provided a solution that improved the accessibility of VLE software especially, for visually impaired users. The software design and implementation followed the object-oriented analysis and design methodology. The requirements gathering was carried out using interviews with the stakeholders, informal conversations and literature review.

The testing was done in chrome and firefox in a windows operating system environment; however, it can run on any other operating systems and web browsers. A fast and reliable internet connection is necessary for optimum performance of the system.

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