

CBT Plugin: Towards Inclusive Computer-Based Testing for the Visually Impaired

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Abstract

Technology has supported and enhanced electronic examinations successfully for years through the use of computers. However, since the invention of computer-based testing examination, the visually impaired persons have not been able to successfully take CBT examinations without external assistance (scribes or mediators). Attempts at addressing this challenge have resulted in solutions which will work only when such students are isolated from their sighted peers, which negates the principle of inclusiveness in learning. This work, through the use of speech technology, provides solutions for some of these issues by creating a voice plugin called CBT plugin, which can be added to already existing computer-based examination platform. The CBT plugin provides a voice facility through which instructions and questions as well as answer options are read to the blind. They are able to respond through limited buttons on the keyboard. Speech synthesis was used to achieve the objectives of this work through the Speech Application Programming Interface (SAPI). The prototype solution was evaluated by target users that are visually impaired students with great satisfaction. Thus, the application will help in creating an environment that provides equal opportunities for all the students in taking competitive examinations. This will improve the current educational system for the visually impaired.

Keywords: computer-based testing; visual impairment; speech synthesis; assistive technology; interactive learning environments

1. Introduction

1.1 Background

Education has witnessed the introduction of new technologies in the last few decades which has enabled the creation of a number of innovative tools aimed at improving educational methods both for the teachers and learners. One of the key areas of the learning process in which such innovations can be applied is examinations which play a direct role in the assessment of students and the measurement of their progress (Papadopoulos & Goudiras, 2004). The use of computer based testing and examination (CBT) has become popular today in institutions of higher learning and several local and international examination bodies. This has made learners' assessment easier to organise and manage. While this provides great experience for learners, the visually impaired learners stand disadvantaged due to the challenges in interacting with the regular electronic devices. Provision of better learning experience for the visually impaired has been the focus of many researchers over the decades. One of such areas of focus is the development of voice-enabled examination systems for the benefit of this significant group of people.

There are 253 million visually-impaired people worldwide among which 36 million are blind (*Blindness and Visual Impairment*, 2017). This is a significant population that needs to be cared for in terms of ICT accessibility. In Nigeria, the past couple of years have witnessed a steady increase in the number of visually impaired candidates who sat for the Unified Tertiary Matriculation Examination for admission into higher education institutions. This is evidenced by the Joint Admission and Matriculation Board (JAMB) who reports that in Nigeria, 201 visually impaired candidates were registered for Unified Tertiary Matriculation Examination (UTME) in 2016, 321 in 2017 which is 18% of total candidates registered ("321 visually impaired candidates to take 2017 UTME-Official," 2017), and in 2018 the number increased to 330 (Adesulu, 2018). This growing number is a clear indication that there is a growing interest in higher education among the visually impaired population. However the enabling technology to cater for their needs particularly in terms of examinations is still inefficient. JAMB, for instance currently uses dictation method for the visually impaired candidates during examinations after the failed attempt of using the Braille Note Apex Machine ("321 visually impaired candidates to take 2017 UTME-Official," 2017; "How blind candidates will write 2018 UTME – JAMB," 2018; "JAMB procures special computers for visually impaired to take 2015 UTME," 2015). The situation is not any better in the educational institutions and examination centers where conventional pen and paper test is gradually being replaced by computer based testing systems. It is therefore important that the visually impaired students are properly integrated into the mainstream educational system in such a way that their impairment does not constitute any form of hindrance to their performance.

1.2 Problem Statement

Computer based testing has come to be stay as a means of assessing students' learning at various levels of education. While this is a convenient way of assessment for the mainstream students, students with visual impairment find this challenging. This is due to the lack of adequate hardware and software infrastructure that will enable them to conveniently benefit from this form of assessment like their non-handicap peers. Educational institutions and examination agencies resort to the use of dictation method through human mediators. This comes with its own issues such as the likelihood for examination malpractices. Special solutions which attempt to address this need for the visually impaired such as the Braille Note Apex system has also failed due to a number of factors including complexity of usage and error proneness from voice input etc. These systems of examination do not allow inclusion of visually impaired students on the same examination platform with other students. There is the need for a system which will address these issues and give the visually impaired students the

ability to confidently take CBT examinations by themselves without losing any sense of dignity and individuality.

1.3 Aim and Objectives of the Research

This work is aimed at providing visually impaired students with an ability to interact with computerized examination system using keyboard and speech synthesis.

The following are the specific objectives of the research work:

1. To develop an automated tool through which the intelligence level of blind persons may be tested at low cost.
2. To incorporate text-to-speech into an existing computerised examination platform.
3. To design a system that allows both blind and sighted student to take exam on the same platform.
4. To develop a more flexible computerised exam platform with a functionality that enables voice plugin once activated.

2 Review of Related Works

Assistive technology with the use of web and speech has been helpful to the visually impaired as several researches have been made to improve on the usability and accessibility of online examination systems. Prior research in the area of e-examination focused mainly on the web platform using speech technologies. Other studies on voice-based learning focused on providing auditory interface to the visually impaired learners (García, Ruiz, & Pérez, 2010). In an attempt at helping the visually challenged and learners with other disabilities, Kanimozhi, Karkuzhali, and Suresh (2017) developed a hardware based system using PIC microcontroller, IOT device, constructed keypad with limited keys like A, B, C, D, forward, reverse and skip. The questions are dictated to the student using voice board; answers are inputted via keypad and saved to the server with the help of the IOT. This system is efficient however, it is specially made for the visually impaired which does not allow the student to experience examination on same platform as other students. Another downside of this is that it is expensive to develop and maintain. Another hardware based solution (Voice Operated Tool – VOT) was developed by Vats, Tandon, Varshney, and Sinha (2016) to better meet the needs of visually impaired students. VOT is a device controlled by human voice. It was designed to uplift the challenges of blind users based on the concept of voice recognition. Users are provided with the hardware equipment and login with thumb impression. This system cannot be used in an inclusive environment since speaking during examinations will not only be a distraction to other students but will also lead to examination malpractices. Another limitation is that voice mismatch may occur thereby causing an error in the examination.

There are a number of voice based solutions proposed to address this need. Sania, Sanskriti, Shewta, Prateek, and Shivam (2015) presented an approach based on voice recognition and voice synthesis (Google voice) with additional feature of multiple choice questions. The system allows for verbal answering of questions. Similarly, Shunmuga, Essaki, and Srinivasan (2014) and Jamunkar, Sawankar, and Buradkar (2014), describe voice recognition systems which have recording systems where the content had been recorded already in a certain format. The blind people are able to hear the recorded content in the system. This way, they can easily know the content and learn in a preferred way and also interact with that system through voice input. The major disadvantage of these approaches is that they have to give a voice input in a clear manner which could result in some mismatch. There could also be noise suppression while giving a long word as input. These solutions also cannot be used in an inclusive environment due to the voice input.

Other researchers such as Junying and Baiwen (2012) present an approach which uses the keyboard to provide guide and feedback by voice. It includes features for management of papers, students, examinations and score reports as well as functions for sending papers, carrying on the examination and adjudicating the papers. Papers can be automatically made by

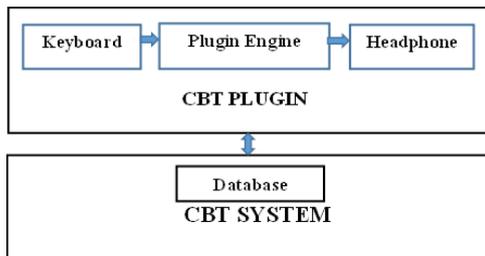
the system once the users set the types of questions, count, scope, difficulty rate and so on. It only accommodates sighted students and students with low vision.

The systems reviewed systems are typical of existing approaches which have successfully implemented the integration of visual interfaces to voice synthesis and to provide auditory access to functionalities in various systems. These systems are either stand-alone systems that are made specifically for examinations or they are systems which make use of voice input. These systems are either too expensive to deploy on a large scale or they fail to accommodate the desire for inclusion of visually impaired students with their well sighted peers. Our solution aims at addressing these deficiencies.

3 The CBT Plugin System

3.1 Analysis of the Proposed System

The proposed system is a computer based system which helps bridge the gap between the sighted and the visually impaired students. The solution consists of a CBT plugin system which readily plugs in to any existing CBT examination system. The CBT plug-in is able to access the examinations database for questions and storage of responses. The interface is established between the student and the system through the keyboard and headphone connected to the computer system as presented in figure



3.1.
Fig. 3.1: An overview of the proposed system.

The design of the system is composed of six independent subsystems that communicate by broadcasting messages on a common CBT plugin infrastructure which serves as the communication as shown in figure 3.2. Each subsystem listens for messages on the infrastructure and pick up the messages to be execute in form of event commands presented in

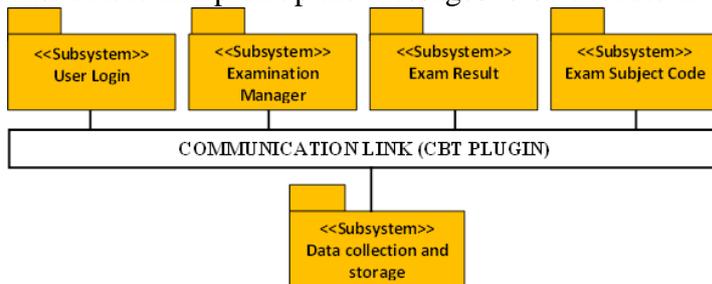


table 3.1.
Fig. 3.2: The CBT plug-in for architectural design

The communication sequence for the CBT plugin for the blind is shown in the figure 3.3. When the plugin is activated, the examinee will have to login and provide any of the commands in table 3.1 through the keyboard in order to accomplish the desired task. The communication sequence shows how the system will be used by the users, it contain a system prompt that say a welcome message to the user, which is followed by set of menu options in form of conditional IF statement.

```
BEGIN
SYSTEM PROMPT 'Welcome! Please enter your username and password'
```

```

SYSTEM Authenticates examinee
SYSTEM PROMPT menu selection
//examinee issues a command
IF the command is to take examination THEN
//examinee issues command to select subject code and to start exam
SYSTEM fetches question from the database
SYSTEM reads out examination questions with instructions to guide
the examinee
//examinee chooses correct answer by pressing corresponding button
on the keyboard
IF the examinee have answered all examination questions THEN
SYSTEM PROMPT submit examination and listen to result
//examinee issue commands
SYSTEM evaluate result and report result status information
ELSE
IF the command is to exit THEN
SYSTEM report good bye message and Exit.
END IF
END
    
```

Figure 3.3: Pseudocode for CBT Plugin for the blind

Table 3.1: CBT plugin keyboard keys and their command descriptions

keyboard keys	Description of command
T	Take exam
1,2	Select the exam subject code
P	Access examinee to exam form
S	Start examination
A,B,C,D	Select answer to a question base on four choices
N	Access next question
R	Repeat question
F	Submit answers to the database
V	Read out the result

3.2 System Implementation

The design of CBT Plugin for the blind was designed to be an event driven system. The implementation of CBT plugin for the blind was broken into three major components;

Speech Interface (Plugin): the speech interface was implemented using Speech Application Programming Interface (SAPI), an inbuilt class library of Microsoft.Net framework which makes easier the implementation of speech in any kind of application.

Using visual basic .net, the following code will be added to all the classes in CBT plugin for the blind in order to access the SAPI synthesizer engine to render text into speech using an installed voice such as Microsoft Anna.

```

Imports System.Speech
Imports System.Speech.Synthesis //help to access the SAPI synthesizer engine
    
```

The SAPI inbuilt functions used are speak() and speakAsync(). The function speak() is a public function used to initiate text-to speech process while speakAsync() reads out text string asynchronously.

Setting up Keyboard Input: This was achieved using KeyPress event handler in visual basic.net. With this, an event is triggered for character key while the key is pressed and release by the user. In order to achieve the stated objectives in table 3.1, specific keys are mapped to

particular functions such that when that key is pressed, the function mapped to it is executed or an event is triggered.

The KeyPress event `e.KeyChar` converts Unicode of the key pressed automatically into uppercase and triggers the specified event. The system therefore only works with upper case alphabet inputs except the login id. The following sample code illustrates how this is achieved:

```
If Asc(e.KeyChar) = Keys.R Then ' R to repeat the question
    ' Speech synthesis code
    speaker.SpeakAsyncCancelAll()
    ' speak out which key is pressed
    speaker.SpeakAsync("You have pressed " & e.KeyChar)
```

3.3 Mode of Operation

The CBT plugin for the blind uses Microsoft Speech Application Programming Interface (SAPI) which is based on concatenative type of speech synthesis technology. The entire system works with voice command (speech synthesis) along with qwerty or normal computer system keyboard that a visually impaired student will be comfortable working with. The application is launched by the user; it receives command through keyboard. Information or question is delivered to the examinee through voice with the aid of SAPI. This enables the blind person to select an answer option through specific keys and also provide other options by pressing an appropriate key provided that will be given in the instruction. Each uploaded question must be answered to go to next question, this continues till examination is completed.

The voice plugin feature is automatically activated for the blind and it can be disabled by sighted students. Upon entering an identification number, the system the system validates the student. If valid, examination subject selection form pops up and upon selection of the desired subject, the system launches the CBT window. The system reads out the instructions which include number of questions to answer and the time allotted to the student. Questions are automatically read to the student with the options A, B, C, and D. The student chooses an answer by pressing the corresponding key on the keyboard. Other key functions may be also used by the student as described in table 3.1. When the time is up and the student has not submitted the answers, the exam is automatically submitted and graded for the student. Another feature of the CBT plugin is that it reminds the examinee the time left when the time allotted is remaining 6 minutes to elapse. The time reminder is triggered every 1 minute interval until the time elapsed.

3.4 System Evaluation

The system was evaluated using usability testing which was performed by a selection of target users. The goal of the usability test was to identify any usability problems, collect quantitative data on participants' performance (e.g., time on task, error rates), as well as determine users' satisfaction.

During the first phase of the testing, eight (8) users were given the prototype to use. Notes were taken on how easy it was for users to accomplish basic tasks for the first time on the system. Other metrics that were measured include; how fast the users accomplished tasks, how many errors users made, how severe the errors were, ease of recovery from the errors and how much the users liked using the system.

Findings from the first phase of the testing showed that the users were satisfied with the user login, instructions guide and the ease of choosing the appropriate key on the keyboard. Time of completion of set exams was also very good. 75% of the users were able to complete the examination within the given time frame (60 minutes) as illustrated in figure 4.1. The fastest completed in 20 minutes, while the least time was 28 minutes and the average time was 19 minutes as illustrated in figure 4.2.

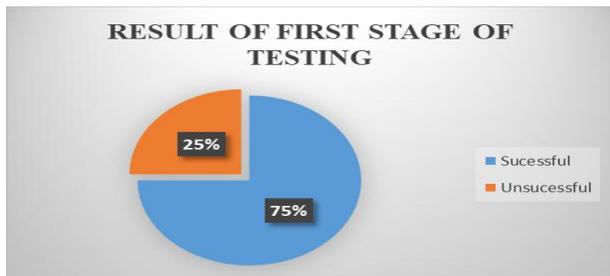


Fig. 4.1: First stage test performance

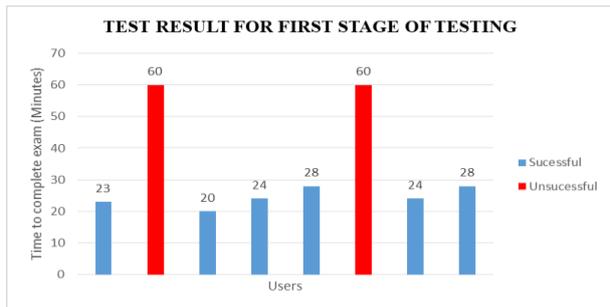


Fig 4.2: First stage test completion times

The various complaints and observation noted in the first phase of testing were implemented and released for the second phase of the testing. Five (5) of the initial testers were involved in this phase and three (3) new users were included to perform tasks different from the first. The outcome of the testing were encouraging, as all the old users were able to complete the task at the given time frame while 2 out of 3 of the new users completed all tasks within the initial time of 60 minutes. The high completion rate of the new users indicates that the initial time can be seen to be moderate, and the initial users may possess low deduction skills. Figures 4.3 and 4.4 show the performance and completion times of the second stage of testing.

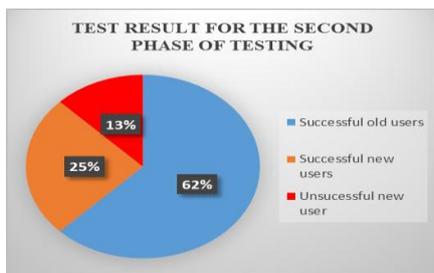


Fig. 4.3: Second stage test performance

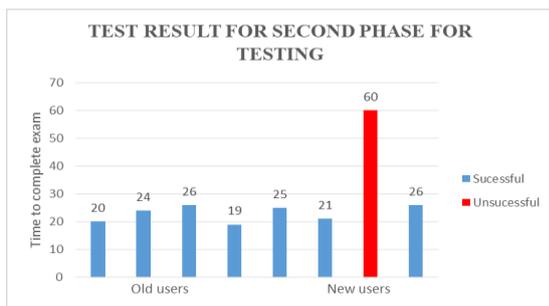


Fig. 4.4: Second stage test completion times

4. Conclusion

The implementation of CBT plugin for the blind using text-to-speech for voice output and input through keyboard, has eliminated the inaccuracy of speech recognition in the existing systems. The features of CBT plugin for the blind which allow the examinee to activate or deactivate plugin, makes the platform usable for both the visually impaired and sighted students therefore reducing discrimination among the students. The system also automates examination process through reading out questions to user and receiving answer via keyboard. It eliminates the need for scribe or an external assistance during examination. Therefore, the primary aim and objectives of the research work has been achieved through the development of CBT plugin for the blind.

5. Suggestions for Future Work

This version of the CBT plugin reads only text based questions. There is need for a version of CBT plugin for the blind that can clearly analyse diagrams to give the examinee clear picture of the diagram with the help of image recognition API.

Another aspect worth considering is the extension of the keyboard capability to handle the full scale keyboard and the provision of a text editor such that the CBT plugin can handle essay-type questions and sub-objective type (short answer) questions in addition to the objective-type questions.

CBT plugin for the blind can also be further developed with a feature that can serve as a tutorial guide for the blind.

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