MyAccessible+ Math: Shining Light on Math Concepts for Visually Impaired Students

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***Abstract*—For some of us, a full understanding of complex mathematical concepts is only achieved through a lifetime of practice. For students with visual impairment, this process is hindered by the inability to process complex mathematical formulae. While computer technologies have successfully transformed and enhanced the learning process, the potential promised by these technologies has not become the reality for visually impaired students. For years, the most effective way to communicate ideas to a blind person has been through either audible conversation or braille writing, both methods having their shortcomings for more complex mathematical analysis. This is the purpose of the MyAccessible+ Math Project; bridging the gap between math professors and students who simply need instructions from a different perspective. The motivation of this study is to introduce a prototype of our web application that will help visually impaired high school students to evaluate their mathematical skills. We hope that the use and further development of our prototype shall open doors to these students in areas of academia and beyond that have until now seemed eternally sealed.**

Keywords–Vision-impaired students; Accessibility; Speech recognition.

I. INTRODUCTION

According to World Health Organization [1], approximately 250 million people in the world have moderate to severe visual impairment that cannot be cured. The National Institutes of Health (NIH) study [2] has found that 14 million Americans aged 12 and older, are visually impaired. The inability to process visual elements is an obstacle for many vision-impaired students. This disadvantage leads to a big knowledge gap between students with vision-impairment and students without disabilities.

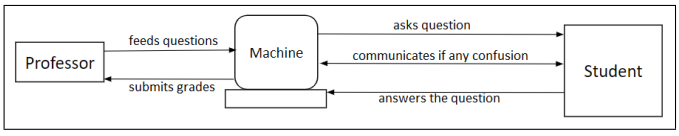

Figure 1. MyAccessible+ Math Design Structure.

The aim of this study is to introduce the prototype of our Web application, MyAccessible+ Math, that helps vision-impaired high school students evaluate their mathematical skills. The basic design structure of the project is shown in Figure 1. Entities associated with the module are explained below:

- Professor: The role of the professor is to add questions and set points for questions. An open-source math visual editor, Wiris MathType [3] is embedded on the website, which makes easier for the professor to add questions for different math topics.
- Machine: The machine represents the ”evaluating module” of the project. This module provides questions to the student. The module also provides help on each question if the student seeks for it. All the communication between the student and this module is done through Annyang.js [4], an open-source speech recognition library. Additionally, the module calculates the overall grade for each student and reports it to the professor.
- Student: The student is the most important entity of this project. The student can use basic navigation commands to iterate through the website. The most useful commands are ’Go to login page’, ’help me’, and ’logout’. Annyang.js [4] library is used for speech recognition. In the future, more commands can be added to extend the scope of the project.

The rest of the paper is organized as follows: *Section II* consists of literature review, which discusses existing techniques that are currently available that facilitate teachers to understand teaching and/or testing challenges and experiences involving vision-impaired students. *Section III* demonstrates the technologies used in the prototype. *Section IV* provides a detailed implementation of the proposed prototype. *Section V* concludes the project along with suggestions for future enhancements.

II. BACKGROUND AND RELATED WORK

For years, the most effective way to communicate ideas to a blind person has been through either tactile methods or audio methods. For example, Braille is a tactile writing system in which characters are physically raised. Audio methods include speech-to-text and text-to-speech representation using speech synthesizer tools.

MathSpeak [5] is an audio method for representing mathematical formulae to blind students. The first step is to scan the mathematical formula and render it in the notation of MathML or LaTeX. The input to the system can be either LaTeX, MathML or AMS-TEX and the system can read equations like text. The system can recognize all alphanumeric characters, all

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Greek letters, and other frequently used symbols in the math formulae. One major advantage of the system is to be able to navigate through different sections of the math equation.

MathPlayer [6] is a plug-in for Microsoft Internet Explorer which was designed for rendering visualization of MathML. It can easily be integrated with screen readers.

The LAMBDA project [7] is funded by the European Union to overcome the problem of accessibility to mathematical formulae. The system consists of a MathML markup language that can be directly translated to the 8-point braille system, which is an extension of the 6-point braille system.

Braille code is used to encode mathematical and scientific notation linearly, by using 6-dot Braille cells. While Braille is suitable for the text representation, mathematical equations are multidimensional, and they may contain fraction, algebra, series, log, and exponentiation [5]. Also, 6-dot braille can represent only alphanumeric characters and a small set of special characters by the 64 combinations of possible dot placements. Thus, by extending the 6-dot Braille system to 8-dot Braille system, 64 possible combinations can be extended to 256 combinations.

This is an excellent choice for a certain context, but by today's digital standards, the use of Braille is expensive [8].

III. TECHNOLOGIES USED

For this project, our main goal is to develop a robust and flexible prototype of an open-source Web application in a structured manner and constantly refine it.

The current version of the application supports a limited number of math topics. New math topics, math questions, and math tests can be added in the later versions. The technologies used for the prototype are explained below:

A. Annyang.js

Annyang [4] is an open-source JavaScript Speech Recognition library that makes adding voice commands to any website super-easy. The student is the most important entity of the project. Navigation through Web pages is done through voice commands.

Table I shows the list of commands current version of the prototype supports. With Annyang, more custom commands can be added in the future to extend the scope of the project.

TABLE I. VOICE COMMANDS LIST

Voice Commands	Action
'new user'	Redirect to the registration page
'let me in'	Redirect to login page
'practice question'	Redirect to the practice questions list
'attempt random'	Randomly selects the question and open it in a new tab
'skip question'	Skips the question and fetches the next one
'help'	Provides more information on a question while practicing a question
'next hint'	Speaks the next hint
'Log out'	Logs out of the system
'Hint one'	Provides the first hint while practicing a question

B. Wiris MathType Editor

Wiris MathType Editor [3] is embedded on Web pages for the professor to add math questions. Math formulae can be exported to multiple formats and are compatible with LaTex and MathML.

C. ResponsiveVoice.js

ResponsiveVoice [9] is an open-source text-to-speech library written in JavaScript, offering an easy way of adding voice to any website or application.

D. Linear Equation Parser

The current version of the prototype supports two types of math problems: Linear Equation Solver and Linear Equation Simplifier.

Jep Java expression parser [10] is used to evaluate the mathematical expressions in this prototype. Jep Java parses and evaluates the mathematical expressions with only a few lines of code. This package allows users to enter a formula as a string, and instantly evaluates it. Jep supports user-defined variables, constants, and functions.

IV. IMPLEMENTATION

MyAccessible+ Math is a Java-based Web application developed using HTML5 and CSS3 as front-end and JSP and Servlets as back-end. In what follows, we discuss the development process and functional requirements of the prototype.

Initially, all the requirements were gathered and analyzed based on Evolutionary Prototyping (EP). EP allows a continuous refinement of the system and is based on the understanding of the requirements by the developers.

A. Functional Requirements

- Home Page (index.jsp): This is a Web page where professors and/or students can login. The machine would recognize if the user is a student or professor based on the username stored in the MySQL database. The home page provides welcome text about the application for vision-impaired students. User can say "new user" to navigate to the registration page. Students will be redirected to dashboard_student.jsp. Professors will be redirected to dashboard_professor.jsp.
- Student Dashboard (dashboard_student.jsp): Only students can access this page. This is a dashboard for students after logging in. Students can use voice navigation commands to go to any page.
- Attempt Questions Page (attempt_questions.jsp): This page provides a list of all practice questions. Student can start practicing random questions by saying "attempt random". Student can say "help" for further info. Figure 5 shows the attempt questions page for students.
- Each Question Page (each_question.jsp): Student lands on this page after choosing a question to attempt. Web page speaks the question on page load. User can say "Repeat please" to listen to the question again or can say "skip question" to skip the question and move to the next question. If needed, the user can ask for the first hint by saying "hint one". Student can ask for more hints by saying "next hint". Figure 6 shows each question page for students where the student can attempt questions one by one.
- Professor Dashboard (dashboard_professor.jsp): Only professors can access this page. Professor can quickly add a question, see the students list, and add a math

topic on this page. Professor can also redirect to those pages for a detailed view. Figure 2 shows the dashboard for the professor. In the future release, the professor would be able to see the overall performance of each student.

- Math Questions Page (math_questions.jsp): Figure 3 shows the math questions page. Only professors can access this page. The professor can add or delete questions for selected math topics.
- Math Topics Page (math_topics.jsp): Only professors can access this page. The professor can add or delete math topics. Once the topic is added, the professor can add questions for that topic.
- Math Quizzes Page (math_quizzes.jsp): Figure 4 shows the math quizzes page. Professor can create a quiz by selecting questions from the list. Since the project is still in a development state, students cannot attempt quizzes yet.

B. Conceptual Design

Following are screenshots of some of the pages that are developed based on functional requirements. In the future, these pages will be modified based on information and feedback from students.

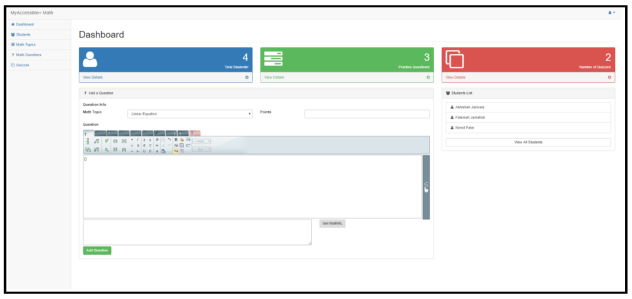

Figure 2. Dashboard professor web page design

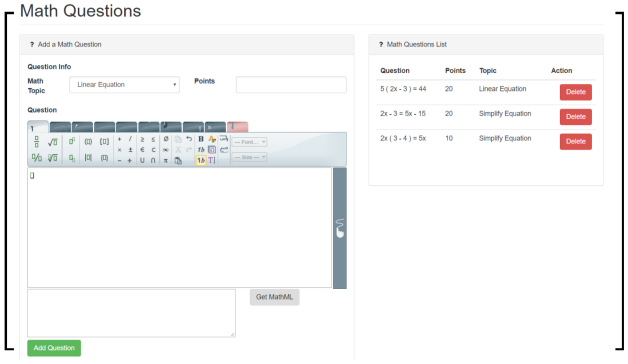

Figure 3. Math questions web page design

1) Professor View: In MyAccessible+ Math, several web pages were designed for the professor to add questions, add math topics, check the students' list, and to create quizzes. The web pages were developed in a way that had good usability, likeliness, and ease of use.

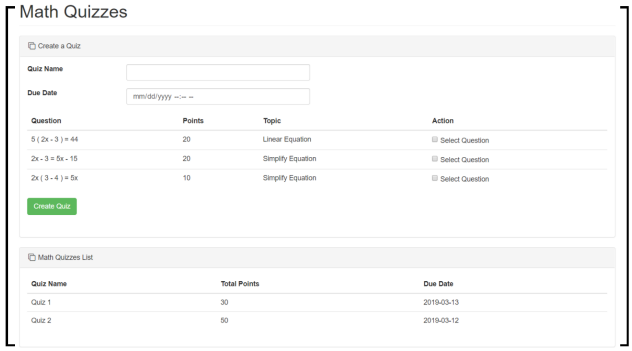

Figure 4. Math quizzes web page design

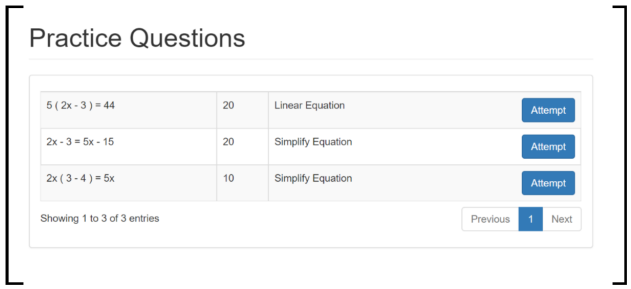

Figure 5. Attempt questions web page design

Figure 6. Each question web page design

2) Student View: Students are an important entity in this project. This application was designed and developed for visually impaired students to test their mathematical knowledge. Therefore, all the web pages that student can access have voice navigation enabled.

V. Conclusion and Future Work

Education is one space that still has the potential to be transformed by technology. Though this project is still under development, it has great potential not only for improving the education of students with visual impairments but also for inspiring the next generation of engineers and scientists.

This prototype is developed to improve math education for vision-impaired high school students. The following improvements could be added in the future release of the work:

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- Evaluation is important while working on an application for vision-impaired students. We are planning to conduct a study at Auburn University with 15 visually impaired students enrolled in a program to evaluate their knowledge in math. We aim to assess their mathematical skills by evaluating their performance using this application.
- The prototype in this research has shown that it is possible to present mathematical expressions to students with little or no vision and test their knowledge in mathematics. The upcoming version of this prototype will include teaching module of the application where students can learn mathematics.
- The current version of the application includes solving and simplifying linear equations. However, different math topics will be added in the future release of the application.
- Verifying and updating information, resetting password for students will be added in the future release of the application.

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