Tools for Teaching Mathematical Functions and Geometric Figures to Tactile Visualization through a Braille Printer for Visual Impairment People

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Abstract

In this article, we showed the features and facilities offered by two new computer programs developed for the treatment and generation of geometric figures and math functions, through a Braille printer designed for visually impaired people. The programs have complete accessible features, in which users with full visual impairments can communicate with the systems via short-keys, and the speech synthesizer. The system sends sound messages that will accompanying the user during all the process to generate geometrical figures or to do a mathematical treatment. Finally, a tactile visualization displays as the results to the person with visual impairment, thus they will can complete their geometry and mathematical studies.

Key words: Accessibility, Braille, mathematical functions, tactile impression, visual impairment.

1. INTRODUCTION

Nowadays, breakthrough technologies have greatly facilitated the access to education, and that evolution trends are present in the teaching process for mathematics and geometry in general. Simplifying the access to certain issues and problems presented in the everyday learning process. Thus, this new technologies are offering new ways to represent and manipulate math symbols, figures and math functions, enabling choices about the content and pedagogy that have never seen before [1].

According to Batista [2]. People with visual impairment can interpret geometric and mathematical concepts from tactile and sound methods. Then, with these concepts in mind, users can discover links and develop spatial sense, designing, measuring, viewing, comparing, sorting and transforming figures and mathematical functions. Thus, you may create resources to help math and geometry teaching with viewing means and concrete materials that exploit the tactile functions to build knowledge, from the graphical interpretation of functions and geometric figures.

Research groups In Brazil has developed some computational tools that communicate with the users via speech synthesis. Thus, helping to perform tasks like text editing, use of calculators, e-mail service, among others [3], Although, many of these programs do not allows the users with visual disabilities have full independence and control, especially when they wants both create and format mathematical functions from their given equation generator, also for drawing geometric figures with their respective tactile impression.

In this research project, we will show two developed solutions for those students; with full or partial visual impairment, can learn and create geometric figures from its mathematical equations, as well as create graphics based on mathematical parameters of the function, without having the user depends on a third person. In this fashion, the system allows them to experience their designs and learn the relations with the functions. Furthermore, these new tools enables a better communication between the teacher and the visual impaired student. In addition, it can have other applications, not just for math classes, we could extend to physics, chemistry, and basic electronics among others. These new systems are thought for people with partial or complete visually impairment, and teachers who deal with visually impaired students.

2. METHODOLOGY

The development and design of both GEOMETRICVOICE and MATGRAFVOICE application software comes from the need of visually impaired people in understanding and creating geometric figures; as well as, generate graphics of mathematical functions, respectively. These programs have common characteristics, like their communication with the user through speech synthesis and the use of a text editor to insert commands, allow the execution of tasks. The voice synthesizer created through the artificial production of human, has the ability to convert text into speech.

The programs allows interaction of visual impaired user, with the computer and its peripherals in an easy and fast way. For visualization, the geometric figures and graphs of mathematical functions need to be shown through a tactile

display [4, 5, 6], this being made possible by the Braille printer that provides printing embossed points [7].

Technological challenges have focused on creating applications with a computational logic and operational structure, based on the difficulties for understanding and specific necessities faced by visually impaired users [8, 9].

We describe the differences of these two applications below:

2.1 GeometricVoice: Geometric figure generator

GeometricVoice provides the design and printing of various types of geometric shapes (regular and irregular polygons, circumferences, ellipses, and polyhydrics) in two and three dimensions, through sound information, which enables data entry into program by the computer keyboard, and special menus oriented to people with complete or partial visual impairment.

The application presents different geometric shapes available in a table within the application, allowing the user to select and enter the data of the geometric shape design. This is the set of functions themselves, through the "Text Editor" we draw a specific geometric figure or change some parameters such as: the chart title, name, and dimensions of the coordinate axes, among others. The following presents the basic structural model of a function:

<function_name> (<function parameters>);

A GEOMETRICVOICE function consists of the name, where we can set the parameters like insensitive case. The function parameters must always go from an open parenthesis "(", and a closed parentheses and semicolons ");" The structure of the functions are specific to the design of geometric figures.

GEOMETRICVOICE consists of three stages. The first is the integration of function codes and their respective parameters in the "Text Editor". The second step processes, refines, and interprets the code of the functions, for further graphical representation. The design of geometric figures in the plane corresponds to the third stage. Once designed the geometric shape, there is the step that validates and interprets the options for printing. The last step corresponds to obtain the printing of various geometric designs in Braille and embossed. In each stage, there are sound feedbacks, if there had been a mistake, the software through voice messages alerts. Thus, noticed that the program is able to conduct a common impression of the complete graph, also; that is, apart from drawing with reliefs we have a representation of figures with ink and shaft together with the description text in Braille format. In Figure 1, we present the stages of Geometric voice.

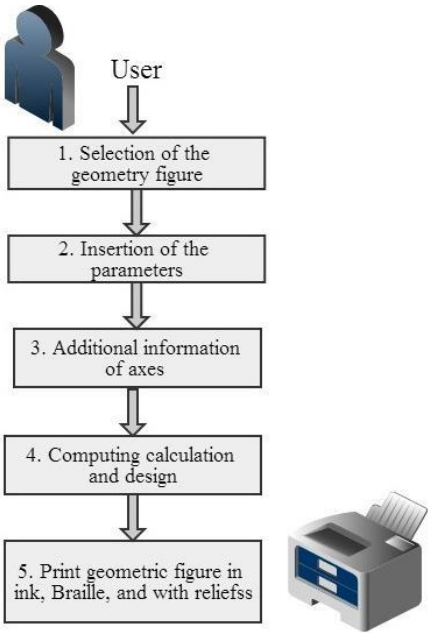

Figure 1. Flowchart with the steps of GEOMETRIC VOICE.

2.2 MATGRAFVOICE. Treatment of mathematical functions and a tactile display

MATGRAFVOICE is a software for mathematical treatment to design any kind of mathematical functions (Algebraic, explicit, order, linear, quadratic, radical, logarithmic and trigonometric) with their graphic representation. The application graphically interprets one or more mathematical functions entered by the user through an editor with accessible texts. After data validation and interpretation by the system, the user can print the chart to complete his studies of mathematics, through a tactile interpretation.

The system begins communicating through speech synthesis, allowing thus the interaction with the system through sound messages that will accompanying the user from the beginning to the end of the mathematical treatment process. In this fashion, with the text editor you can enter text, insert, edit, delete and import mathematical functions, this facilitates the user to perform the tasks to insert and work on a mathematical function. In the text editor, we created some commands (reserved words) which are the tasks that will run through the wizard. The text editor contents can be printed for your tactile interpretation using the Braille spelling of Portuguese and considering the Mathematical Code Unified (CMU), which is who sets the standards for encoding mathematics and scientific writing notation in a linear way, and it is turning in a compact markup language, readable by a person with visual impairment

The proposed methodology for the treatment of mathematical functions shown in Figure 2 show the five main components of the system.

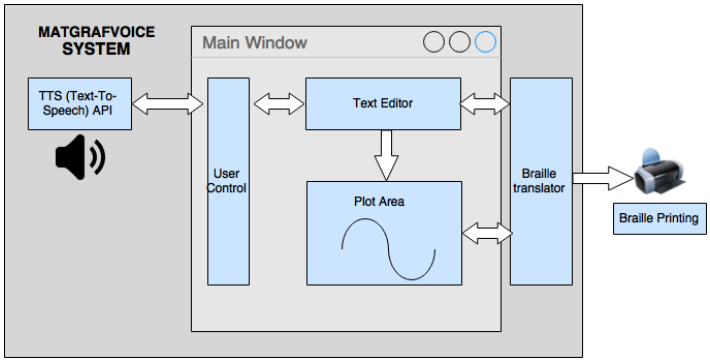

Figure 2. MATGRAFVOICE System Components.

To insert a mathematical function in the text editor, the user can use the insertion assistant of predefined functions in the system. According to Gupta [10], we can encoded any two-dimensional mathematical expression in a linear sentence for the correct use of parenthesis, thus the expression, see (1).

$$\left(\frac{x}{1+x^2}\right) \quad (1)$$

The user begins writing the linear function as (x / (1 +. The power function can be inserted through the wizard, selecting the function (pow), the assistant asked the user to enter the base value of the exponent and then the user by pressing the ENTER key, the power function is written as pow (x, 2), finally the wizard complete the linear expression. See 2.

$$(x/(1+pow(x,2))) \quad (2)$$

The help form insertion assistant with predefined functions helps people with visual disabilities does not have to worry about mathematical notation entered to the computer keyboard. Finally, in the Table 1, we shown as the expression (2) will be printed in Braille terminology, based on the linear mathematical expression and how the speech synthesizer will read the expression.

Original expression	$\left(\frac{x}{1+x^2}\right)$
Linear expression	$(x/(1+pow(x,2)))$
Braille expression	⠷⠭⠌⠷⠼⠁⠬⠏⠕⠺⠷⠭⠂⠼⠃⠾⠾
Expression to the voice synthesizer.	left parenthesis , X over, left parenthesis, one plus, left parenthesis x squared , right parenthesis, right parenthesis , right parenthesis .

Table 1. Different representations of mathematical expressions.

3. RESULTS

The print tests for the two applications used the Emprint SpotDot printer; it allows both print Braille and ink, enabling access to the results of mathematical modeling and mathematical functions treatment, for either people with visual impairments or people without any problem in vision.

We can print the text editor contents, in either Braille format or ink with normal font, and we can print the functions in diverse degrees of relief with a high resolution. The printer is pre-configured to work together with the programs developed in this research.

The tests were conducted using paper white Braille writing in A4 format with dimensions 297 x 210 mm, while the selected font size was 29, according to the manufacturer's recommendations since the ideal measure for reading the text in Braille [13].

Then it presents the results of printing the applications figures.

3.1 Design of geometric figures with GeometricVoice

The user can open the insertion wizard of geometric figures and select one of different geometric shapes. For the particular case of creating the circle, the user can choose the option with the same name or using the arrow keys or by pressing the "C" key to go to the options of geometric figures that begin with that letter.

If the user presses the "Enter" key on the "Circumference" option, the program will open the form for entering the circumference parameters, where the user can select a texture, as different spaces for numerical information.

A result from scanned copy of the printed circle design in Braille and reliefs is shown in Figure 3, where the design of the circle on paper is equivalent to drawing designed on the computer screen. However, printing ink numbering axis presents one variation due to numerical conversion to Braille.

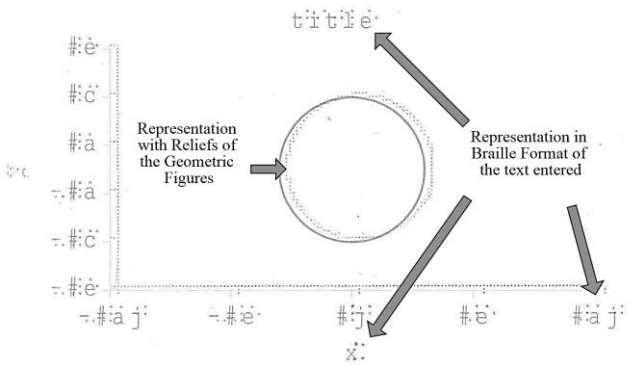

Figure 3. Scanned Image of Circumference Printed in Braille and Reliefs.

3.2 Design of mathematical functions with MatGrafVoice

The Figure 4 presents the generated chart in your tactile description. It can be seen the printed design in relief of mathematical function (1) in the Cartesian plane. Moreover, it shows the numerical information of the X and Y axes, as well as the names or labels and the title of the printed figure in mathematical Braille format in Portuguese, fulfills the analysis for users with visual impairments. Furthermore, interpret the dynamics of the function for better understanding and further comprehension; allow the study of this important subject.

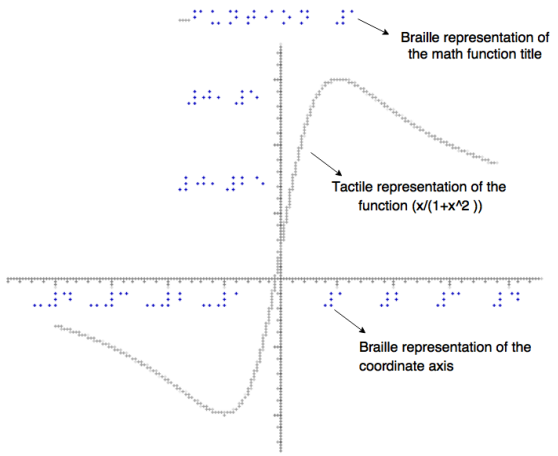

Figure 4. Print embossed in Braille and description of the expression$(x/(1 + pow(x, 2)))$, limits (-4,4).

4. CONCLUSIONS

The developed programs have fully accessible features; that allows to the visually impaired user interact autonomously with the system, through their shortcut keys and the voice synthesizer. Furthermore, it contains designs and colors that helps the user with partial visual impairment, prepare in a simple and flexible way, geometrical figures and mathematical functions with high reliefs; as well as, the description of the parameters that constitute them, such as numbering and labeling the axes, and flow charts with the title in Braille format.

The GEOMETRIC VOICE is an educational software tool featured for visually impaired people. The software developed allows in a targeted way, project, design, and print reliefs of a diverse set of geometric figures in two dimensions. Impressions with relieves also contains a common representation in both ink and Braille texts, in their title and axes.

With MatGrafVoice we can design and asses various types of mathematical functions given the configuration parameters as their upper limits, lower limits and increments. Thus, it is easier to visually impaired do several tests and get their own conclusions, which are fundamental for the learning process in mathematics and open a wide range of knowledge areas.

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