2007

MathOMatic Blocks: An Automated, Tactile, Interactive Method of Teaching Mathematics to Blind Students in the K-12 Environment

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Abstract

Learning mathematics has always been a daunting task for the visually impaired student. For the most part, a task that restricted their entry into careers based on the reading and writing of mathematical equations. There have been some notable exceptions, but for the most part education in the domains of math, physics, computer science and engineering have been beyond the grasp of blind students. In the current work, we discuss the basic problems associated with learning mathematics and discuss possible solutions to the problem.

1 A Bit of History

The presentation of textual information to the blind has a long history, normally traced back to Louis Braille in the mid 19th century. In reality, the earliest efforts to help the blind cope with everyday life began much earlier, but also in France. Legend has it that Louis the Ninth, after a defeat in the crusades set out to aid the "Quinze-Vingts" (in English, "fifteen score or 300) hospice to help the crusaders blinded as punishment by the Saracens. While the story is not actually true, it did have a positive impact on the treatment of the blind in Paris and in 1483 became the basis of the first fund raising event for the blind. Louis was canonized later as St. Louis, which became an important city in the United States, which became a center of Braille development in America.

In the late 18th century, Valentin Hauy had several encounters with blind residents of Paris, one of them a young boy, blind since childhood who became Hauy's first student. Teaching the boy first with wooden block letters, his student was eventually able to read the back-side of a printed page by feeling the impressions of the type. This was just the beginning, and within a few years Hauy had opened a school for the blind with more than twenty students: the Royal Institution for Blind Children, at 68 Rue Saint-Victor. One of the central projects in the school was the printing of embossed books for the blind, the first one being his "*An Essay On The Education Of The Blind*[1]*.*" One of the bound volumes of this work was given to Marquis d'Orvilliers, a nobleman

[1] The Bernard Becker Collection In Ophthalmology at the Bernard Becker Medical Library of Washington University School of Medicine has a copy of Haüy's original book, which he personally gave at Versailles to a noblewoman who would later lose her entire 10,000-volume library in

from a small village east of Paris—Coupvray, the town in which Louis Braille was born in 1812. As they say, the rest is history (Braille History).

2 Text and Math are Very Different

Braille notation includes a set of Braille cells, each composed of six dots, which when raised in the appropriate configuration, form the characters needed to represent textual information. But, with six dots, we can represent only 2^6, or a total of 64 different characters. So, even for text, we have a problem (if we wanted to represent the upper case, lower case and the digits form 0 to 9, we would require 62 different characters). Therefore the Braille character set has to multiplex the basic alphabetic characters and numbers to get by with needing only 36 characters to represent the entire alpha/numeric set of characters. This, and other neat tricks allow the Braille code to be used to present readable text to the blind reader.

But, Braille is linear and most of math is not. Even in teaching arithmetic, we need more than a single line of numbers to represent problems in addition, subtraction, multiplication and division. Printed or Braille embossed pages of learning materials are marginally useful as they are static in nature. Refreshable Braille devices are limited to a single line of Braille and therefore can't do the job either. A product called Math Blocks (http://www.unclegoose.com/BlocksBrailleMath.html) extends the traditional simple basic math bocks used in the educational process for decades. Both of these products are useful, but require constant supervision by a teacher or parent – particularly in the case of visually impaired students.

But, we shouldn't dismiss this concept without further investigation. The Braille math blocks offer the student the ability to interact with math problems directly and in two dimensions. There suddenly emerges the ability to manipulate a problem by moving blocks about on a flat surface. Blocks that are labelled both in text and in Braille. But, without supervision, the learning process is severely limited, even in the case of sing blocks.

3 Using the Computer as a Tutor

The concept of the Braille math block can be extended and enhanced using computers. Not super computers, but rather everyday home computers. The idea is simple: automate the process of tutoring using Braille based math blocks. But, the concept doesn't stop here, as the same system can be used with any sort of math blocks: text, Braille or combinations of both.

3.1 The Physical Aspect

A simple touch sensitive device is used to present the math problem and then to track the student's progress in solving the problem. The teacher, parent or student simply lays out the math blocks on a scored grid (scored to insure alignment of the blocks) and then the student has access to more blocks to place on the grid to represent the answer to the problem. Each block caries a tiny RFID chip which when selected and placed in a scored location on the scored tablet

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the Revolution. Copies exist there also of the numerous books written by subsequent administrators of the school for the blind in Paris, including Guillié, Dufau and Guadet. In another odd coincidence, this library is located in St. Louis, Missouri informs the computer about which number, operator or letter was placed in which position. Figure 1, shows how such a layout might look.

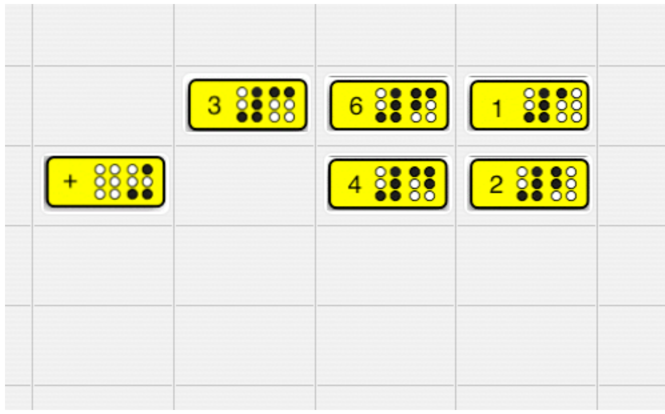

Figure 1. A simple problem represented in MathOMatics

The student has a box of extra Braille math blocks at hand and selects appropriate block to place on the tablet. As these blocks are being placed, the computer gives verbal response to the student. For example, in presenting the answer to a simple arithmetic problem, the student forgets to carry from the previous column. The computer would verbally explain that an error has occurred and tell the student generally what went wrong (see Figure 2). The spoken words are shown in the display in this figure.

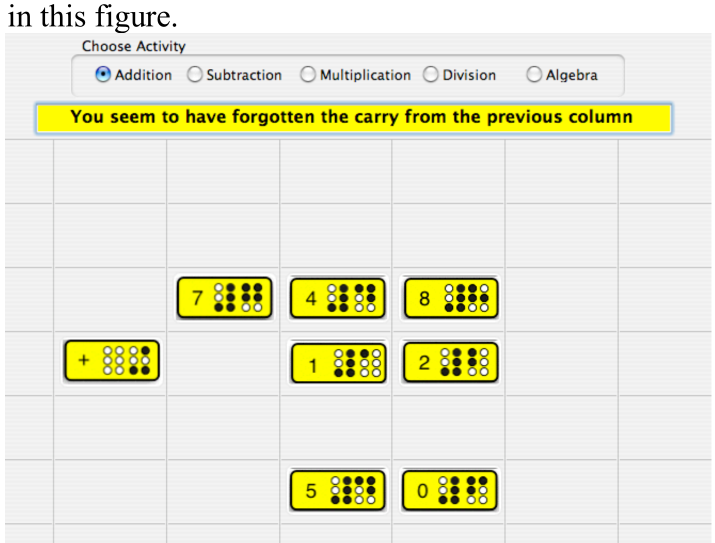

Figure 2. A sample of feedback from the system

3.2 The Research Component of the Project

There are several interesting research components to the system displayed above. They fall into the following areas.

3.2.1 Tracking the Braille Math Blocks

As the blocks are placed on the scored tablet, the computer must be able to track each block that is currently in use. By using the touch sensitive tablet and RFID encoded blocks, we should be able to accomplish this task. We will need to experiment with these technologies to build a procedure that works in a reliable manner in an ever-changing environment.

3.2.2 Internal Representations

In order to help the student, the computer must be able to convert actual physical locations of blocks into some meaningful representation of the world on the scored tablet. Our intention is to use one of the well known context free mark-up languages for this task. We are considering MathML, LaTeX and open math to achieve this goal. Initially, the placement and movement of the blocks on the tablet will be used to manipulate a tree structure based on the blocks and their positions on the tablet. This is a relatively simple algorithm that is easily updated as blocks are placed, deleted or moved from the tablet.

The next step involves the real-time translation of the internal tree to our selected math mark-up language. The selection of the math mark-up language will be a function of which equation solver we finally employ.

3.2.3 Solving Problems Internally

In order to give advice to the student in anything beyond the simplest of math problems, we will need to employ a sophisticated equation solver such as Maple from the University of Waterloo in Canada (http://www.maplesoft.com/). Protocols will have to be developed for passing information back and forth from our software to Maple as the next step in the interactive tutoring process.

The tutoring process will progress with the student. In early stages of MathOMatic training, the student will receive more help than in later learning experiences. The system will maintain a history of problem types encountered and solved and then base levels of help based on experience to date. There will also be a "panic button" area on the scored tablet to allow the student to request more help by simply touching that section of the tablet's surface (naturally marked in Braille).

4 Conclusion

The MathOMatic system has the potential of combining several attractive technologies to help teach mathematics to visually impaired students. Other teaching systems such as the "Virtual Pencil" (http://www.hentermath.com/) developed by Ted Henter, of JAWS fame, is also an interactive math-learning tool. However, it is constrained to a computer keyboard with no tactile representation or interaction with the problem. As math problems become more complex, their two-dimensional nature is an important clue concerning their solution. This is not readily feasible with a strictly compter based teaching system. Even with the addition of a refreshable Braille device, the student is still restricted to a one-dimensional view of a two-dimensional world.

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[**Virtual Pencil:**] http://www.hentermath.com/