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AutOMathic Blocks: The Next Step

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Abstract

The AutOMathic Blocks system was designed to give young blind students the ability to learn arithmetic and beginning algebra through the use of manipulative blocks and computer tutoring. The system is currently in development at the University of San Francisco. It immediately becam clear that the use of computer supported manipulative blocks had a much broader domain of application than originally assumed. In the remainder of this paper, we present an overview of the AutOMathic Blocks system, as well as our new plans for extending the system to "The Next Step."

Introduction

Imagine yourself a second or third grader learning complex addition. Your are given the following exercise to solve.

```
   7 4 8
+    1 2
```

Not a terribly difficult problem, but it does require the concept of "carry" to arrive at the proper solution. As you begin to write the solution, the teacher notices that you have written the number 50

```
   7 4 8
+    1 2

     5 0
```

as a partial answer to the problem, and recognizes that you are on the way to an incorrect solution. You have neglected to consider the carry from the least significant column. If you were a sighted student, after some mentoring by your teacher, you would simply erase the 5, replace it with a 6 and carry on with your work.

If, on the other hand, you are a visually impaired student, you would face several problems in solving this exercise. A brief list of these issues would include,

1. The printed presentation would be of no use to you.

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[1] The AutOMathic Blocks system was initially funded through a grant from The Jesuit Foundation at the University of San Francisco.

2. If the problem was presented on Braille paper, corrections are almost impossible
3. The two-dimensional nature of the problem would not be apparent.
4. If you are at least, a minimally proficient Braille user, there is a high probability that your teacher would not be able to help, as he/she would most likely not be proficient in Braille.

The problem can be mitigated through the use of a simple, but efficient tool – Braille math blocks. Using this tool, your teacher needs no knowledge of Braille, and can follow your progress in the problem solving process (See figure 1).

If the arithmetic is simple, the teacher is facile in arithmetic, the teacher has the proper training in special education and has the extra time to spend with you at school and at home, the problem solved with these simple blocks! Well, not likely. Arithmetic rapidly gets more complex as the student learns subtraction, multiplication and division and with these complexities comes more problems for the visually impaired student. The next steps include simple algebra and geometry - and even less human support in the learning process. At this point, many parents are effectively out of the teaching and mentoring loop and the paucity of special education math teachers becomes a bigger and bigger problem[Lee – 2005; Olszewski – 1998].

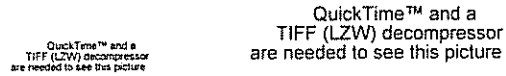


Figure 1. Braille Math Blocks from Uncle Goose & Independent Living

The proposed AutOMathic Blocks system would have tracked the student electronically through the simple example above giving the following advice at the same point, or earlier, than the teacher or parent would have intervened.

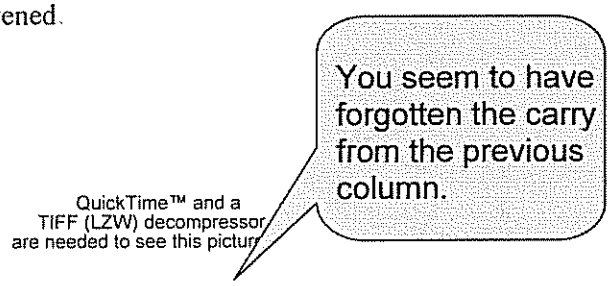


Figure 2. A sample of feedback from the system which is delivered in an **audible** form.

All system feedback comes from a computer working together with a specialized version of the Braille math blocks and can be rendered via speech or refreshable Braille, or both. Multiple national spoken and Braille-based information can be supported by the system using tools already developed by our group (See figure 2 above).

The AutOMathic Blocks system is not restricted to simple arithmetic. From simple addition to beginning algebra, the AutOMathic Blocks system will provide the visually impaired student their own personal teacher / mentor, and the cost of the final system will be low enough to be affordable by schools and students.

While the current example seems quite simple, it is only the forerunner to much more complex arithmetic and mathematics. And, without the basics, later materials will become difficult or impossible to learn. Foundational material is critical to continued learning of math and then to other math based disciplines such as physics, chemistry, engineering, and the list goes on.

The AutOMathic Blocks system is designed to take visually impaired students from basic arithmetic through beginning algebra concepts. Key elements in building a foundation to enter science, technology, engineering and math careers.

What the system will offer the visually impaired students includes the following:

1. The use of manipulative blocks to form and solve problems. Manipulatives have long been used in teaching and are considered powerful tools in the learning process of disciplines such as mathematics [Gardner – 2006; Zuckerman – 2005; Ross – 1993].
2. For the visually impaired, manipulatives provide a method of perceiving the math problem in a similar way as do sighted students. This means the problem can be "seen" in its actual form.
3. A learning tool that can be used without the presence of parent or teacher.

The Use of Blocks

A simple input device is used to layout the math problem and then to track the student's progress in solving the problem. The actual input device selection is an integral part of the proposed research. A prototype has already been built [Karshmer – 2007] using blocks with Braille and barcodes, which are placed on a touch pad device (See figure 3 The system runs smoothly without any machine induced errors, but is too expensive for general use as the its parts cost almost $600 independent of the software to drive them. The Braille math blocks we use are simple wooden blocks resembling those used in the popular board game, Scrabble. On one side is the actual number or symbol, overlaid with the Braille equivalent of that symbol. On the reverse side we have placed the barcode for the character on the front side (See figure 4)

Figure 4. Blocks used in prototype system.

The problem setup and solution phases entail the following actions by the user

- The Braille – Bar-coded blocks are kept in a reservoir for easy access by the student
- The student selects the characters needed for the current problem selecting them by their Braille tag.
- The selected block is passes over a simple and inexpensive barcode reader and the computer verifies the block's contents verbally
- The student then physically selects a place on the workspace grid and places the block in that space – this placement is automatically recorded by the computer
- This process is repeated until the problem is laid out on the grid.
- At any point in the process, the student can review the laid out block by simply passing a finger over the grid.
- The student then presses a Braille labeled button which starts the solution phase
- The answer is then laid out in the same manner as the problem.

During the setup and solution phases of the learning process, the computer builds and maintains an internal model of the problem's current status. The students can add new blocks from his/her block reservoir or remove blocks to be returned to the reservoir. In all cases, the status of the internal representation is updated and advice can be tendered.

The student, will of course, use the Braille tags on the blocks and get verbal feedback at appropriate times. In order to remove or replace a block in the reservoir, the block will be tracked in a manner similar to the input process. In this way, the current state of the scored tablet and the reservoir can be tracked and internally represented

The scored tablet contains Braille-based column and row identification tags, which will be used as a coordinate system conceptually shared by the student and the system much as we do in spreadsheet applications.

System Restrictions and Extensions

The prototype system (Figure 3 above) was designed based on certain physical constraints, namely the minimal size of the Braille blocks and the availability of a reasonably sized touchpad device. At that time the Iveo device was selected with a touch sensitive area of 12" x 9" (30.4cm x 22.8cm. these dimensions allowed us to build a user workspace grid of 9 x 9 math blocks or a total of 81 blocks. Recently a different touchpad device has been identified with a larger touch sensitive area, 17" x 13" (43.1cm x 33cm). This device is attractive as it is considerably less expensive than our original device and can easily support a working surface supporting more than double the number of blocks supported by the Iveo device.

The original block grid of 81 blocks used almost 65% of the touchpad, leaving the remaining 35%, or 38in^2 (242.6cm^2) for command buttons. The new touchpad, containing a 162 block grid (see figure 5) would have free space of 39% or 86.2in^2 (554.6cm^2) which could easily

accommodate the requisite control buttons leaving considerably more space for the Braille blocks.

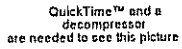
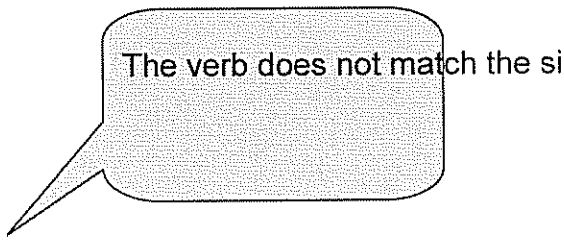


Figure 5: A larger useful Braille block grid

The new real estate on the larger and less expensive touchpad opens new windows of opportunity for teaching with Braille-based manipulative blocks. An obvious example is the teaching of simple grammar – a simple problem of matching verbs with the singular/plural nature of nouns (see figure 6).



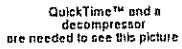


Figure 6: A simple example of tutoring in grammar (Braille not shown)

The leap from entering and managing numeric Braille blocks in arithmetic to character Braille blocks in grammar is not difficult. The basic algorithms that accept blocks in the AutOMathic system are essentially the same as required for grammar. The primary difference is the integration of simple grammar checking software in place of the arithmetic checking currently used in our project.

Current Project Status

The grammar project is currently in its formative stages. The new touchpad device has been purchased and is software is being developed to integrate it into the algorithms already developed for the Iveo. The search for an appropriate open source grammar checker is also underway. We expect to have a working prototype operational by the end of May.

Conclusions

Already having done the basic groundwork in the construction of a self-paced, computer-assisted math learning system, we feel that "The Next Step" is close at hand. It will allow young blind students to easily create and learn the basic skills needed for correct and effective writing skills so badly needed to succeed in their later life.

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