An Interface for Math e-Learning on Pen-Based Mobile Devices

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Abstract

We explore how pen-based mobile devices may be used for mathematics instruction. It is convenient to split the function of a math e-Learning system between these light-weight devices and a server running a content management system. Functions such as sketching and entering and displaying mathematical expressions can be performed on the mobile devices, while other functions such as computing plots and checking student answers are more conveniently performed on the server. This distribution of computation is invisible to the student, who merely sees a pen-based instructional system in a web browser.

1 Introduction

The use of computers in the classroom has had mixed success. On one hand, computers have inspired a host of instructional techniques, allow new modes of presentation, and support a wide range of innovative student evaluation methods. On the other hand, since they are not suitable as the *only* medium of instruction, computer workstations are usually relegated to special "computer labs" or a few are placed at the periphery of a classroom. We consider that some less intrusive use of computing equipment might allow a more flexible deployment. In this paper we explore how the use of calculator-sized mobile devices may be used to provide a different sort of e-Learning experience. In particular, we examine how software components may be assembled to provide a suitable platform for mathematical e-Learning on mobile devices.

There are at present numerous small mobile devices that can access the Internet: cell phones, smartphones, PDAs, mobile gaming devices, netbooks and small tablets. Which kind is most suitable in an elementary school or high school classroom? In this setting it is difficult to use an ordinary PC, even if it is a laptop, because it occupies the student's desk and a student has no space to open books or for perform written work. Moreover, current PCs are unsuitable for brief use since it needs several minutes to boot. Suppose that a teacher says during math class, "Let's plot the graph of this quadratic function using your computer." If it takes 5 minutes to boot and load software, the lesson stops and students lose focus.

With this in mind, we identify the following as characteristics necessary to use computers as easily as rulers or compasses in a general classroom:

- hand-held portability
- quick power on/off
- simple manipulation.

We propose pen-based mobile devices as the optimal computer in a math classroom. These have a small form factor and a sufficient resolution. Further, most can be operated with a stylus or a finger. This provides the necessary input flexibility.

In terms of function, we consider the following as the basic requirements for a mathematics e-Learning environment:

- displaying math expressions
- inputting math expressions
- including graphs of elementary functions
- freehand drawing
- automated checking of student answers.

This paper investigates the potential feasibility of such a system. We first report on a school classroom experiment, in which we devised some model math lessons using pen-based mobile devices and gave these lessons in elementary and junior high schools. We then outline the technologies used to assemble the prototype system.

2 Related works

Fujimoto[1] developed AsirPad, a computer algebra system with a pen-based interface on PDA, using the technology of InftyEditor[2]. AsirPad can communicate with Risa/Asir[3] through OpenXM protocol[4], and calculate mathematical expressions inputted by handwriting. This system was used to present a lecture about RSA cryptography at a junior high school[5]. Encryption and decryption in RSA use division of large numbers. The students learned how to encrypt/decrypt their messages through calculations

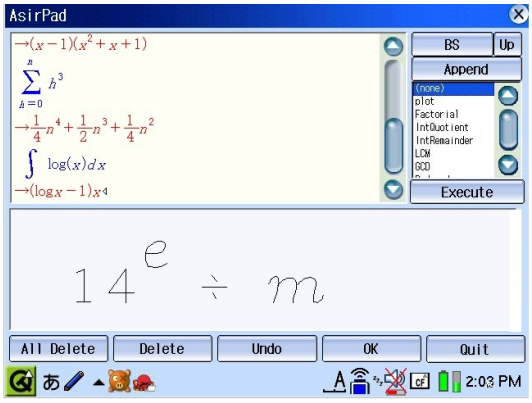

Figure 1: AsirPad on Zaurus

by AsirPad. They could input mathematical expressions and calculate without any special training. In this case, it was effective to use pen-based mobile device on the student's desk.

Hivon et al[6] undertook an experiment on a secondary school using graphing calculators. Calculators were connected to hub by the cable every four sets, and all hubs were linked to the teacher's PC by WiFi. A teacher could recognize students' individual work and display them by a projector.

These positive experiences encouraged us to explore the possibility of mobile devices in math classroom. The devices used in these investigations were insufficient, however, to go further: the former has no way to support quizzes the latter has only simple functions.

3 A Classroom Experiment

3.1 A Web-Based Educational Support System

We developed a web-based educational support system in order to distribute math quizzes and understand the state of the students' activities. This system comprised a server accessed by pen-based mobile devices. The cost of the pen-based mobile devices was a potential issue because every student in the class needed such a device. Based on cost, and on potential for student engagement, we adopted the Nintendo DS mobile gaming device.

The system has three functions (1) providing a math quiz, (2) visualizing results of the students' answers, and (3) sending messages to a teacher. Figure 2 shows the system requirements. Students' answers can be assessed on a teacher's PC and displayed to the class on a projection screen.

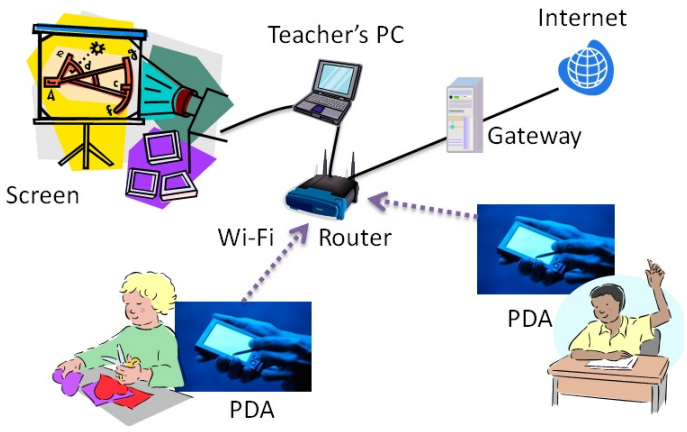

Figure 2: System requirements

3.2 Lecture on Euler circuits

We gave a lecture on Euler circuits for grade 6 students in an elementary school using this system[7]. The number of students in the classroom was 40. The goal of this lecture was to find common properties among Eulerian graphs. The flow of the lecture are as follows:

1. Review: even and odd numbers
2. Introduction: seven bridges of Königsberg
3. Activity: investigation of 10 graphs
4. Presentation: results investigated by each group
5. Confirmation: common properties among Eulerian graphs
6. Exercises: judgment whether given graph is Eulerian or not
7. Conclusion

We used our system at the above step 1, 3, 6 and 7. In step 6, we provided Euler circuit quizzes implemented by JavaScript. A state of students' activities was displayed on teacher's PC in real-time. By this, the teacher could advise students in trouble quickly. In step 7, students sent teacher a summary using Nintendo DS. The teacher displayed them on a screen and could introduce in a short space time.

Elementary and high schools in Japan have a problem that students are shy and do not readily share their opinions in class. However, it turned out that with this system students wanted a teacher to hear their opinions.

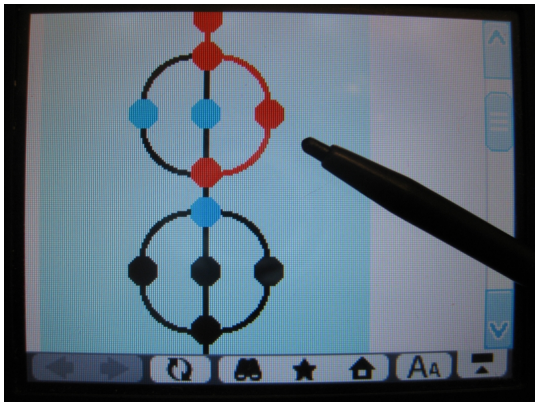

Figure 3: Euler circuit quiz on Nintendo DS

Figure 4: Nintendo DS on a student's desk

4 A Lighter Client for Math e-Learning

4.1 CMS Clients in the General Classroom

We could see that our web-based educational support system showed promise in the previous lecture. We could also see, however, our approach taken to authoring and management of material would not easily scale up to delivery of full courses in a real setting. Easing this task is the function of a Course Management System (CMS) or Learning Management System (LMS). After examining a number of alternatives, we chose Moodle from among the open source CMSs. This choice was in part motivated by Moodle's wide adoption at universities. The main difficulty with CMS in our setting was that use from PCs is assumed so the client screens are too rich to display on mobile devices. We needed a lighter client screen/application for our CMS. The

mTouch[8] and MLE-Moodle[9] are client applications of Moodle for the iPhone and cell phones. In this paper we address to client modules providing a lighter screen.

4.2 Moodle Lite

There exist some modules and extensions of Moodle for mobile devices. These include Moodle for Mobiles[10], the mobile mode of fs_moodle[11], Moodle Lite[12], and from these we chose Moodle Lite, developed by Education Center in Kagoshima University. Moodle Lite is a set of client modules including user certification, forum, quiz and feedback functions. The modules are independent of the ordinary client modules in Moodle and Moodle Lite accesses the same databases as Moodle. This means that teachers can use the full version of Moodle on their PCs and students in class can use Moodle Lite. This flexibility allows students to use Moodle from mobile devices, such as the Nintendo DS and iPhone and also from a PC, when desired (for example, for homework). The main challenge was to determine how the needs of mathematical content could be met on this platform. We now discuss these, in turn.

4.3 Rendering Expressions: MathML CSS

Moodle has some filters for mathematical expressions. The TeX filter is included in the official distribution of Moodle and can display mathematical notations in TeX as images. The images are created on the server. A page with lots of images, however, is too computationally intensive for certain mobile devices. The jsMath filter[13] uses TeX fonts installed on the client. In case of devices where TeX fonts cannot be installed such as the Nintendo DS, the browser cannot display them well. The ASCIIMathML[14] can translate TeX notation to MathML. To compound problems, the Opera browser on the Nintendo DS and Safari on the iPhone do not support MathML natively.

Korpelainen[15] developed a JavaScript plugin based on ASCIIMathML. It creates images of mathematical notations only for browsers that do not render MathML. On the other hand, we adopted MathML CSS[16] for rendering in such browsers. This function was implemented as a plugin to the HTMLArea, the default editor on Moodle, using ASCIIMathML and the mathml.css stylesheet distributed by B.R. Miller[17]. Figure 5, 6 are screen shots showing mathematics in a browser on the Nintendo DS and iPhone.

4.4 Expression Input: BrEdiMa

The next version of Moodle may have a math expression editor DragMath[18]. This, however, is implemented by Java and cannot run on certain important mobile platforms, including the Nintendo DS and iPhone. We therefore used

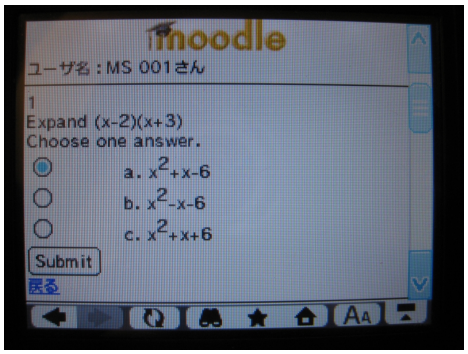

Figure 5: MathML on Nintendo DS

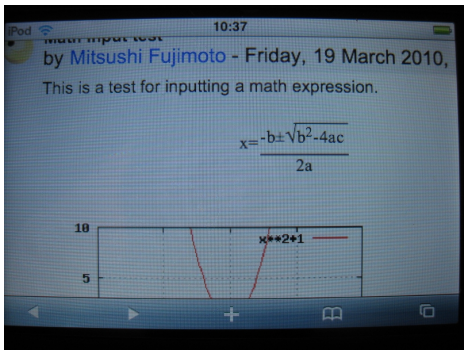

Figure 6: MathML on iPhone

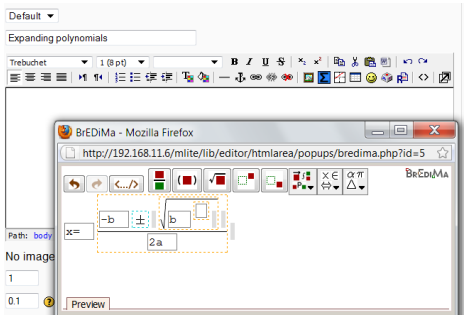

Figure 7: BrEdiMa

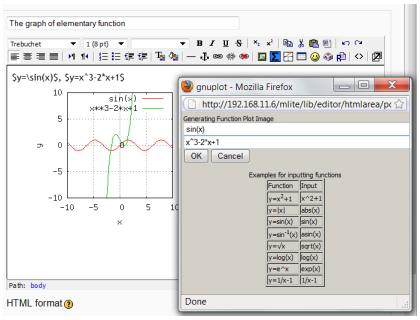

Figure 8: gnuplot dialog

BrEdiMa[19] as a math expression editor for our prototype. It is similar to DragMath but is implemented in JavaScript, and is very light.

4.5 Graphing Output: Gnuplot

In mathematical instruction, graphing of functions is crucial. We implemented a plot function for our prototype using gnuplot[20] on the server side. Teachers can include graphs elementary functions quizzes and students can create plots from their mobile devices. Figures 7 and 8 are screen shots of BrEdiMa and a sample of graph obtained by gnuplot.

4.6 Freehand Sketching

It is also useful to add a freehand drawing dialog in student's client screen. We would like to use SVG as the drawing format in consideration of the relation to MathML. There is an open source drawing tool SVG-edit[25]. One difficulty is that a user cannot use this tool in Opera on the Nintendo DS or Safari on the iPhone because a drag action for drawing is recognized as

a page scroll. We will need to handle the following touch events to overcome this problem: `touchstart`, `touchmove`, `touchcancel` and `touchend`.

4.7 Checking Student Answers

There are some approaches to this item, including Maple T.A.[21], STACK[22]. Both systems are known as computer aided assessment systems for mathematics, and they provide an authoring and a management for math quiz to Moodle. STACK(System for Teaching and Assessment using a Computer algebra Kernel) was developed by Sangwin[23]. It can evaluate students' answers using a computer algebra system, in this case Maxima[24]. Furthermore, it can give students various suggestions corresponding to their answers using *Potential Response Trees*. Unfortunately, math expressions in STACK are displayed by jsMath. This cannot be used in our prototype since this conflicts with our MathML CSS approach. We are planning to develop a computer aided assessment system that can communicate with various computer algebra systems including Risa/Asir through OpenXM protocol based on the technology of AsirPad.

5 Conclusions and Future Work

We have started a project to develop a prototype environment for Math e-Learning. We have dubbed our activity the *Mathellan* project, abbreviating **Math**ematiccs **e-L**ea**rn**ing.

In this article we have presented the components we believe are needed in an interface for pen-based mobile devices in Math e-Learning. Our prototype implements certain components using MathML CSS and gnuplot. In order to complete the environment, we have to implement a freehand drawing dialog and a computer aided assessment system like STACK. By using MathML and SVG, we expect to realize a interactive dynamic assessment environment.

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