RESEARCH ARTICLE

A New Mathematics Input Interface with Flick Operation for Mobile Devices

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Abstract

Developing online test environments for e-learning on mobile devices will be useful for increasing drill practice opportunities. To provide a drill practice environment for calculus using an online mathematics test system, such as STACK, we developed a flickable mathematics input interface that can be easily used on mobile devices such as smartphones and tablets. The interface developed using JavaScript and MathDox is mainly for entering mathematical expressions. When the alphabet or number keys on the interface are touched, various candidates of operation appear around the touched key. Flicking in either the leftward, rightward, upward, or downward direction performs the required operation, depending on the selected key. The number of key taps required for entering mathematical expressions on a mobile device using the proposed mathematics input interface is compared with the number of key taps required in direct input; direct input involves using the built-in keyboard of a device. The number of key taps is considerably reduced when using the new mathematics input interface. Furthermore, our new mathematics input interface is compatible with traditional keyboards. The keyboard is automatically selected based on the types of devices being used.

Keywords: STACK, math input, mobile devices, flick operation.

1. Introduction

In recent years, learning management systems (LMSs) are being used for learning courses in many educational institutions. One of the most popular features of an LMS is online testing for determining students' understanding of a subject. Typical online tests include multiple-choice, true-or-false, and numerical input, but the mathematics input online test is gaining popularity in science education. In the mathematics input test, mathematical expressions are entered as answers and are automatically assessed, usually using a Computer Algebra System (CAS). WeBWork (Baron, 2010), Maple T.A. (Zivku, 2015), MATH ON WEB (Kawazoe et al., 2013), Numbas (Perfect, 2015), and STACK (Sangwin, 2013) are examples of online assessment systems that are used in educational institutions worldwide.

Online testing is useful for determining students' understanding of a subject; it offers the advantage of instant feedback through automatic assessment, and students can practise by solving many online test questions by themselves. Furthermore, if questions are designed such that they are automatically generated with random variables, students can repeatedly practise different questions, thereby improving their understanding of a subject.

Online drill testing can be delivered not only using PCs but also through mobile devices such as smartphones and tablets to help students practise anytime and anywhere. However, the problem of mathematics input complexity arises for questions requiring the entry of mathematical expressions as answers rather than multiple-selection or number input types of answers. For example, when students answer $x^2 + 5x + 6$ to the question asking for the expansion of the expression $(x + 2)(x + 3)$, they have to enter the expression x^2+5*x+6 in the answer space. However, when users enter the expression in which numbers and symbols are combined using smartphones, it is necessary to switch the smartphone keyboard screen many times; this requires 19 key touches.

In fact, the difficulties in entering mathematical expressions are not limited to smartphones; there are difficulties when using a tablet and a PC as well. There are some approaches to overcome these difficulties, which are discussed in the next section. In this paper, we introduce a new type of mathematics input interface with flick operations for mobile devices. This interface enables students to enter mathematical expressions easily; it also gives them more opportunities to practise through online testing in e-learning systems using mobile devices.

This paper is organised as follows: we analyse some mathematics input interfaces and identify problems with them in section 2. The flickable type of mathematics input interface is introduced in section 3, and its mathematics input efficiency is discussed briefly in this section. We summarise the paper in section 4.

2. Examples of mathematics input interfaces

As described above, to reduce the difficulties in mathematics input, several interfaces have been proposed. For example, Maple T.A. features an 'Equation Editor', and mathematical expressions are displayed in a 'two-dimensional' manner (for example, $x^2 + \frac{x+1}{2}$). The equation editor increases the efficiency of recognising mathematical expressions, particularly indices and fractions, and supports their input in smartphones and tablets. When users enter mathematical expressions through these devices, switching between letters and numbers/symbols is required, and the equation editor does not reduce the complexity of the mathematics input process.

To increase the input efficiency of STACK, MathTOUCH (Shirai et al., 2014) and interfaces utilising MathDox (Nakamura et al., 2014) were proposed. However, it is assumed that they are used mainly on PCs. MathTOUCH runs as a Java plug-in, and it is not supported by some mobile operating systems (OSs) such as iOS. MathDox was developed using JavaScript, but it is not supported by mobile devices because it is not designed for touch operations.

To reduce the difficulties in entering mathematical expressions using mobile devices, we propose the use of a flick input interface that is often used in mobile devices, particularly by Japanese people. We used STACK and developed a mathematics input interface with a flick operation, which is expected to facilitate drill practice through online testing on mobile devices. We will introduce this new type of mathematics input interface in the next section.

3. Mathematics input interface with flick operation

We decided to use JavaScript to minimise the dependency on mobile device OSs. We had already developed a conversion filter from MathDox to Maxima, and we used MathDox for describing entered mathematical expressions, which was another reason to adopt JavaScript for developing the new interface. This section provides an overview of the interface and explains the process for entering mathematical expressions with a simple example. To determine the efficiency of mathematics input using the new interface, we compared the number of key touches in the new interface with the number of key touches required with a conventional keyboard. Furthermore, in the last subsection, we discuss implementing the flick operation in traditional keyboards and the automatic selection of keyboards, depending on the devices that students use.

3.1. General specifications

Figure 1 shows the basic layout that is displayed when the interface is activated. The user can input numbers using the '123' key and alphabets or Greek letters using the 'xy' key in the left column.

When the user taps the 'fx' key, options such as exponential and trigonometric functions become available. Keys for basic operations keys are in the right column.

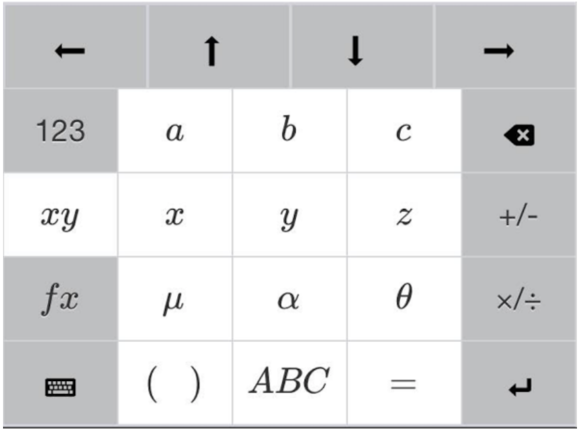

Figure 1. Basic layout of the flickable mathematics input interface that is displayed when the interface is activated.

3.2. Entering mathematical expressions

Figure 2 shows an example wherein the expression $x^2 + 5x + 6$ is entered as the answer for the expansion of the expression$(x + 2)(x + 3)$. An upward flick in the direction of the 'x' key (figure 2, upper left) causes the index input state to appear (figure 2, upper middle); the user can tap the '2' key to enter the index (figure 2, upper right). Then, by tapping the '+/-' key and flicking in the upward direction (figure 2, lower left), the '+' operator is entered. To enter$5x$, the user simply taps the '5' key and flicks in the leftward direction (figure 2, lower middle). After entering '+', 6 is entered by tapping the '6' key (figure 2, lower right). As seen in figure 2, the product of a number and x or y that often appears in mathematical expressions is built into the interface; this results in a reduction in the number of key touches.

3.3. Estimation of input efficiency

Table 1 provides a comparison of the number of tap operations required in direct input using a traditional keyboard and that required in flick input using the interface keyboard. Note that the direct input starts from the alphabet keyboard, and the flick input starts from the state depicted in figure 1. In addition, the process of entering numbers by leaving the alphabet keyboard and holding down the number switching key is not adopted. As seen in table 1, the number of key touches is obviously reduced, leading to a reduction in the number of steps required for mathematics input. It is remarkable that fewer key touches are required for the input of functions, particularly when entering trigonometric functions.

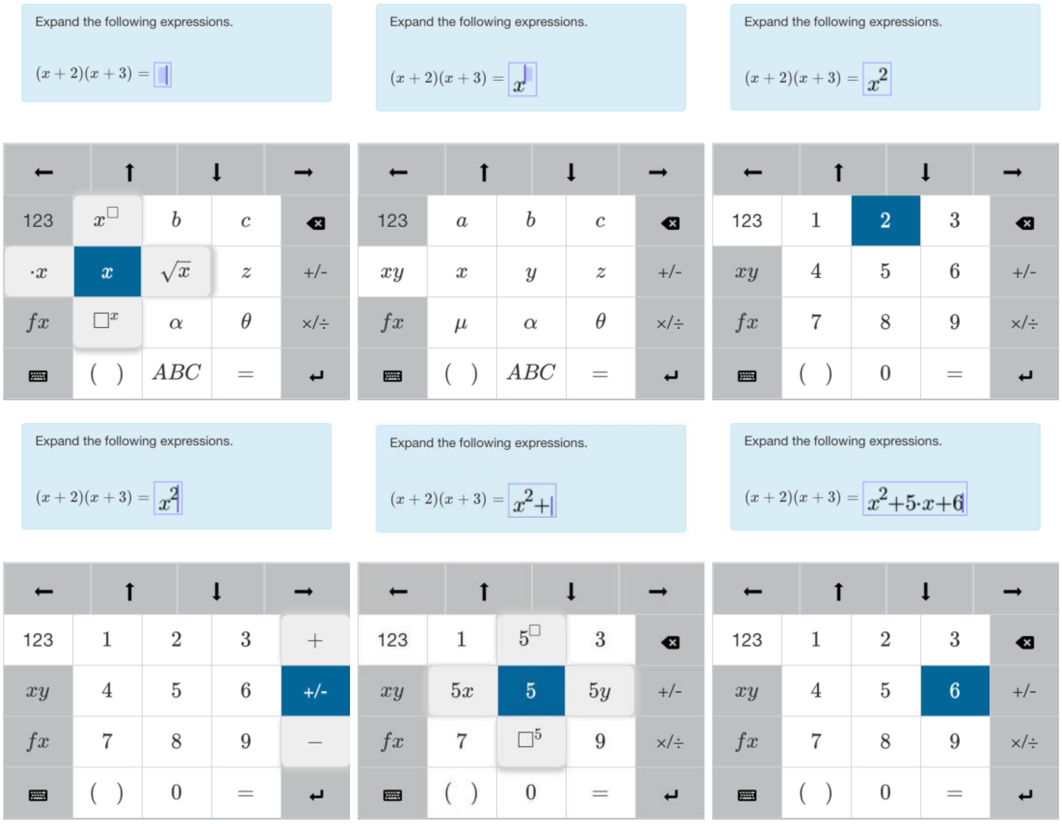

Figure 1. Procedure for entering mathematical expression $x^2 + 5x + 6$. The figure should be read from left to right and from top to bottom.

Table 1. Comparison of the number of tap operations in direct input using a traditional keyboard and in flick input using the interface keyboard.

Mathematical expressions	Number of tap operations	
	Direct input	Flick input
$x^2 + 5x + 6$	19	8
$3x^2 - \frac{2x}{(x^2+1)^2}$	36	13
$2xcosx^2$	23	7

We conducted a usability test at a university in Nagoya, Japan. We asked 29 students to enter the following five mathematical expressions by using both a traditional keyboard and the new flick input keyboard.

$$(a+b)^2, \frac{y}{x+1}, \frac{1}{\sqrt{x^2+y^2}}, sin(\pi x) + e^x, \frac{2xsinx}{(cosx+1)^2}$$

After they entered these mathematical expressions, we conducted a survey on usability and satisfaction levels. The survey questions were based on the following five parameters: learnability, efficiency, difficulty or ease in making corrections, rememberability, and the intent to reuse. These parameters are originally from Jakob Nielsen's five goals of usability (Nielsen, 1993). Table 2 lists the questions and the results of the survey.

The ratings are averages based on the responses of 29 students with the maximum rating being 5.0. The higher the ratings, higher are the usability and satisfaction levels. We can conclude that the usability and satisfaction levels are higher when the flick input method is used to enter mathematical expressions rather than the direct input method.

Table 2. Summary of the survey on usability and satisfaction levels based on Nielsen's five goals of usability.

Questions	Direct input	Flick input
It is easy to learn how to input math	3.0 (1.2)	3.5 (1.0)
I can input math quickly and easily	2.6 (1.1)	3.2 (1.3)
It is not confusing and easy to correct	3.0 (1.2)	3.1 (1.1)
I remember the method that I learnt at the rehearsal	3.0 (1.1)	3.1 (1.1)
I will use this method to input math the next time	2.9 (1.3)	3.2 (1.4)

Numbers in parentheses denote SD.

3.4. Implementation of flick operation to traditional keyboards

As can be seen, users cannot enter many letters such as d and t when they use the flickable mathematics input interface described earlier in this section. The alphabets and symbols available in our mathematics input interface cover most of the letters and symbols used in the introductory mathematics test. However, the letter t or v cannot be entered; these letters are often used as variables denoting time or velocity in physics. Therefore, we implemented the flick operation using a traditional keyboard. When the icon on the lower-left side of the keyboard displayed in figure 1 is selected, the keyboard changes to a full/traditional keyboard. Figure 3 shows an example where a mathematical expression is entered from a full keyboard using the flick operation. In this example, we consider a physics test in which the letters v and g are used to denote velocity and the gravitational acceleration constant, respectively. In a full keyboard, candidates of operation appear horizontally over the tapped key (figure 3, centre).

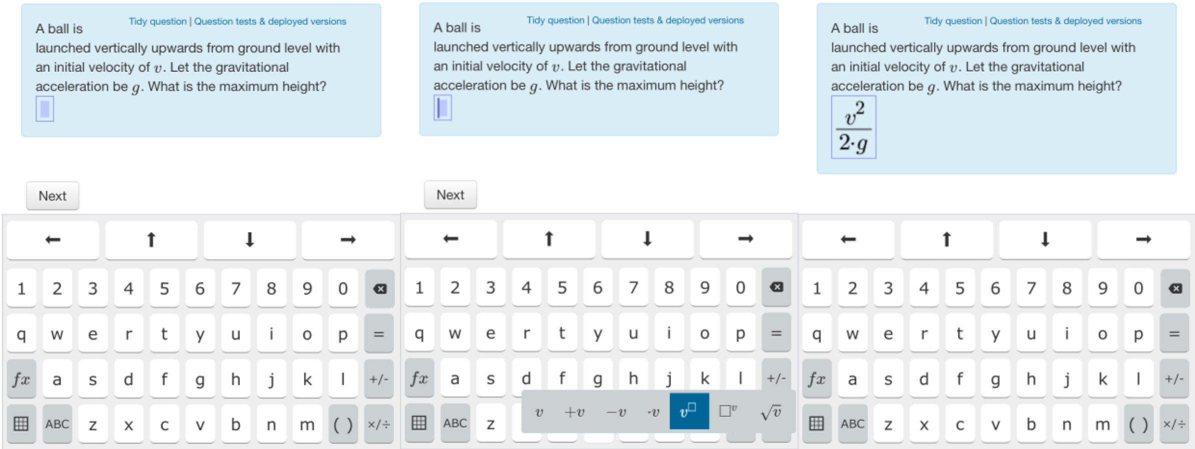

Figure 3. Procedure for entering mathematical expression $\frac{v^2}{2g}$ from full keyboard using flick operation.

3.5. Automatic selection of keyboard based on types of devices

We have demonstrated the working of our new mathematics input interface. We believe that the numerical keyboard (figure 3) is suitable for smartphones, and the traditional keyboard is suitable for tablets; the MathDox input process is suitable for PCs, depending on the screen size and usability of the physical keyboard. Therefore, by default, the numerical keyboard and traditional keyboard appear in smartphones and tablets, respectively. It is possible to switch between these keyboards.

4. Conclusion

For students taking online mathematics tests, online test environments for e-learning in mobile devices are considered to be useful for increasing drill practice opportunities. Therefore, we developed a mathematics input interface with a flick operation, using STACK, for taking online mathematics tests. The demonstrations using the interface in the preceding sections confirmed that the number of key touches is reduced; the usability survey indicated a positive response from students who used the interface. Furthermore, we implemented the flick operation in traditional keyboards and solved the problem regarding the non-availability of alphabets in numerical keyboards.

5. Acknowledgement

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