USABILITY EVALUATION OF MOBILE INTERFACES FOR MATH FORMULA ENTRY

Yasuyuki Nakamura
Graduate School of Informatics, Nagoya University
Nagoya, 464-8601, Japan

ABSTRACT

STACK is an online testing system that can automatically assess mathematical formulae. When working with STACK on a smartphone, inputting mathematical formulae is time-consuming; therefore, to solve this problem a mathematical formula input interface for smartphones has been developed based on the flick operation. However, since the time of development, an increasing number of smartphone types have been developed, making the verification of such interfaces important. We organised the problems of each device and verified the effectiveness of the flick operation for formula input compared with conventional text input.

KEYWORDS

Mathematics E-learning, Mobile Interface for Math Input

1. INTRODUCTION

Due to the Covid-19 pandemic, online education has attracted attention in recent years, and the introduction of e-learning using LMS is rapidly accelerating. One of the important functions of an LMS is online testing, and the conventional formats of online tests that can be automatically graded include correct/incorrect, multiple-choice, numerical input, and short-answer input. However, when trying to measure students' understanding of science and mathematics subjects through online tests, it is important, for example, for students to input answers to calculation questions using mathematical formulae rather than selecting the correct answer from a list of options. In view of this need, the use of systems that can automatically grade answers entered in mathematical formulae, that is, mathematics e-learning systems, is becoming increasingly widespread. Representative mathematics e-learning systems include STACK (Sangwin, 2013), Numbas[1], WeBWorK,[2] and Möbius[3]. A barrier to the use of these systems is the effort required to input mathematical formulae, and it is usually difficult to input complex mathematical formulae in the systems. This is especially true when using a mathematics e-learning system on a mobile device, such as a smartphone.

To solve this problem, Nakamura et al. developed FlickMath, a mathematical formula-input interface for STACK that can be used on mobile devices (Nakamura, 2017). This dramatically reduces the number of taps on the smartphone when entering mathematical expressions. Shirai et al. also developed an interface that, like kana-kanji conversion in Japanese input, presents candidates with mathematical formulae using a machine-learning algorithm and allows the user to input mathematical formulae by selecting them (Shirai, 2014).

However, since the development of such formula input interfaces, various smartphones have been launched, and screen sizes have become more diverse. Even though they are developed in JavaScript and have fewer hardware and software dependencies, they still need to be validated on a larger number of devices. It is also important to investigate the types of interfaces that are effective for students these days. Therefore, we conducted a survey with 65 students on the use of the FlickMath formula input interface.

---

[1] https://www.numbas.org.uk/
[2] https://webwork.maa.org/
[3] https://www.digitaled.com/mobius/

2. USAGE SURVEY

In the usage survey, 65 students were asked to input three mathematical expressions, $(a+b)^2$, $\frac{y}{2x+1}$, $\frac{1}{\sqrt{x^2+y^2}}$ from a smartphone using both the conventional text and flick input methods. The input time and input error rate were obtained as objective data, and choice of preferred input method between text and flick input and their impressions were obtained as subjective data.

First, the smartphone types used by the 65 respondents were iPhone 8, iPhone XR, iPhone SE, iPhone SE3, iPhone 11, iPhone 11 Pro, iPhone 12, iPhone 12 mini, iPhone 12 Pro, iPhone 13, iPhone 13, iPhone mini, iPhone 13 Pro, iPhone 14, iPhone 14 Pro, Galaxy, Pixel 6, OPPO Reno3 A, and Xperia 1 II. Most of the respondents were iPhone users (89.2 %) which is more than the 67% share of smartphones in Japan[4]. Of the 65 respondents, 38 found it easy to input text, and 27 found it easy to input flicks. Eight of the 38 participants who answered that text input was easier to use said that flick input might be easier once they got used to it, thus indicating the potential for flick input.

The data of 39 of the 65 respondents who answered both text and flick input, excluding those who took more than 30 minutes to input both, were then included in the analysis and are summarised in Table 1. It can be observed that the input time is shorter for flick input than for text input. Histograms of the input times for text and flick inputs are shown in Figure 1. Text input has a relatively large amount of data with long input times and a wide distribution, whereas flick input shows, on average short input times, except for exceptionally long-time data. Paired two-sample t-tests showed no significant differences in the input time. A scatterplot of the input times for the text and flick inputs is shown in Figure 2. There was a weak positive correlation, except for the data of the maximum text and maximum flick input. It can be assumed that the students in the data with the maximum value of flick input were those with fast text input times and were relatively familiar with the operation of the device. Therefore, it is expected that once students become accustomed to flick input, the input time will be much shorter. Table 1 shows that the error rate of the flick input is higher. As mentioned earlier, flick input is easier to use once the user is used to it, and it was assumed that the error rate was high because the user was not used to it.

Table 1. Comparison of the average time taken to enter the three formulae for text and flick input, respectively, and the percentage of incorrect entries

Input method	Average input time [s]	Incorrect entries [%]
Text	525.9	12.0
Flick	516.5	16.2

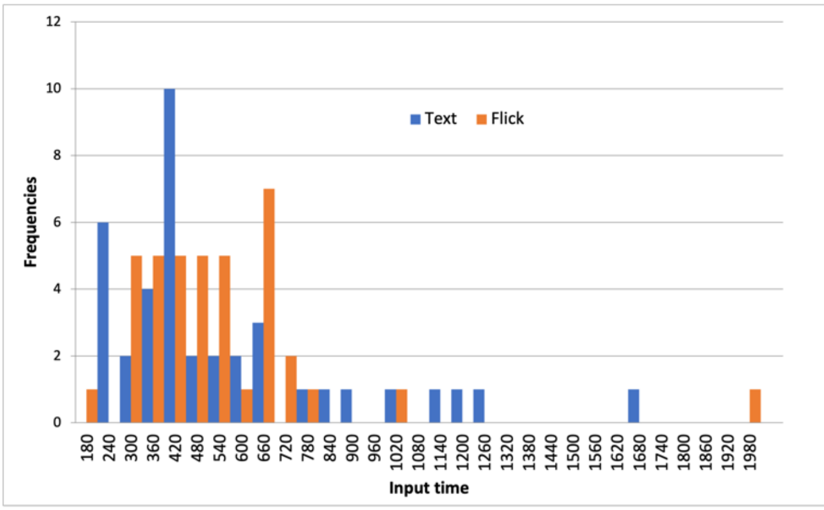

Figure 1. Histogram of input time for text and flick input

[4] https://gs.statcounter.com/vendor-market-share/mobile/japan

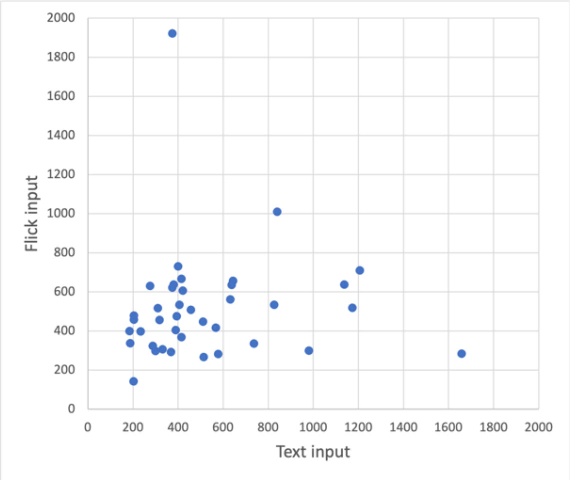

Figure 2. Scatterplot of input times for text and flick input

As for operation problems, it was reported that the flick input interface did not appear and flick input operations were not reflected, but same problem did not occur on the same device repeatedly, therefore, the problem is not reproducible and needs to be investigated in more detail.

3. CONCLUSION

We conducted a usage survey to determine whether flick input, which was developed for inputting mathematical formulae on smartphones, could be used without problems on a range of new devices. Although the reduction in input time of flick input was not superior to that of conventional text input, we were able to identify a potential situation in which flick input would be preferred, as it would increase efficiency once the user becomes familiar with it.

Our conclusion that once people are familiar with flick input, it is more effective for inputting mathematical formulae may be optimistic. However, given that flick input reduces key taps for input dramatically (Nakamura, 2017), it is a reliable prediction that flick input is more effective once users are familiar with it. Free-text student comments have been included. “I found the flick operation difficult as I am not used to it, but once I learnt the operation, I thought I could answer faster than with text”. “I found it difficult because it was not the keyboard I normally use. However, I thought that once I got used to it, flicking might be easier”. “Flick input was confusing at first, but once I got used to it, I thought it would be very easy”. “I did not understand it at first, but once I got used to it, I thought I could use it quickly”.

In addition a student noted, “I found it difficult at first to input formulas by flick because I was not used to the input method, but once I understood it, I could easily input formulas with a single click, and it was easy to use because there was no need to input extra formulas. I also felt that the input system was highly effective as it utilised the characteristics of computers, and education is also progressing on tablets”. As mobile devices are increasingly used in the field of education in the future, it will be important to improve the input method. For this reason, it is expected that flick input will improve formula input and, in turn, expand the possibilities for learning with mobile devices.

ACKNOWLEDGEMENT

This work was supported by JSPS KAKENHI Grant Number 21H04412.

REFERENCES

Nakamura Y. and Nakahara T., 2017. A New Mathematics Input Interface with Flick Operation for Mobile Devices. *MSOR Connections*, Vol. 15, No. 2, pp. 76082.

Sangwin, C., 2013. *Computer Aided Assessment of Mathematics*, Oxford University Press.

Shirai, S. and Fukui, T., 2014. Development and Evaluation of a Web-Based Drill System to Master Basic Math Formulae Using a New Interactive Math Input Method, *Proceedings of the 4th International Congress on Mathematical Software*, Seoul, Korea, Lecture Notes in Computer Science 8592, Springer, pp.621-628.