Intelligent Editor for Authoring Educational Materials in Mathematics e-Learning Systems

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Abstract. E-learning systems for mathematics, such as STACK, Maple T.A., and MATH ON WEB that are able to assess answers using mathematical expressions, have been used for mathematics education at universities. The means for inputting mathematical expressions using current interfaces in these mathematics e-Learning systems are cumbersome not only for students entering their answers, but also for teachers authoring educational materials. In most editing software, teachers need to enter mathematical expressions according to LaTeX-style or computer algebra system-style. This exerts a heavy toll on teachers who have never used these systems. For general use of these systems, it is important to improve the means for entering mathematical expressions. In this study, we developed an intelligent editor for authoring educational materials in mathematics e-Learning systems by implementing a mathematical input interface, named MathTOUCH. This interface allows users to enter the desired mathematical expressions through predictive conversion that converts obscure linear strings presented in a colloquial-style into suitable formats. The results of our previous investigation show that MathTOUCH allows higher level of performance than the standard interfaces. Therefore, the proposed editor is expected to overcome the problem of inputting mathematical expressions in e-learning systems for mathematics education.

Keywords: Mathematics e-learning systems · Mathematics interfaces

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1 Introduction

In recent years, e-learning systems have gained popularity of use in higher-education institutions in accordance with the development of information and communications technologies. These systems offer multiple features such as providing teaching materials, message boards for discussion, and online testing. In particular, online testing is an important feature for self-directed study and measurement of students' abilities.

In online mathematics testing, several systems such as STACK [1], Maple T.A. [2] and MATH ON WEB [3] are used at several universities in JAPAN. These systems enable students to enter a mathematical expression directly as their answer. However, the current standard input interfaces for these systems are cumbersome for novice learners to enter their answer. To improve this issue, Fukui and Shirai have proposed a new mathematical input interface, named MathTOUCH [4–6]. This interface facilitates predictive conversion from a colloquial-style mathematical text to suitable two-dimensional mathematical expressions.

Meanwhile, we have proposed mathematics e-learning questions specification (MeLQS) for sharing questions among different systems [7]. We are also developing the system for authoring questions according to MeLQS. However, the input procedure for mathematical expressions is also troublesome for teachers authoring educational materials.

This study aims to address this shortcoming by introducing MathTOUCH, an intelligent-type mathematical input interface, as mentioned above. We present an intelligent editor for authoring educational materials in mathematics e-learning systems by implementing MathTOUCH.

2 MathTOUCH: Math Input Interface

2.1 Overview of MathTOUCH

Educational materials for mathematics e-learning systems are authored by an HTML editor that allows users to embed media or an equation into their editing text. Currently, there are two ways to enter mathematical expressions, namely text-based interfaces and structure-based interfaces.

Text-based interfaces such as LaTeX use only characters. These interfaces represent mathematical expressions with inline text. To represent relationships between mathematical elements, users need to input characters according to a command syntax explicitly. It is hard to use for novices [8] because these inline text notations for mathematical expressions are not as intuitive as desired.

Conversely, structure-based interfaces allow users to enter mathematical expressions using individual symbols and mathematical structures graphically from menu palettes. It is quite friendly for novices but they need to have previous understanding of the structures of the mathematical expressions. For instance, if users want to input the expression $\frac{x^2+3}{2}$, they need to choose the fraction symbol first, thereafter they insert $x^2 + 3$ and 2. This procedure is different from writing procedures on paper, so this type of interface also causes usability problems [9].

To address these issues, we propose an intelligent-type mathematical input interface, named MathTOUCH. This interface allows users to enter the desired mathematical expressions from obscure colloquial-style strings [4,5]. For instance, in the case of the expression $\frac{x^2+3}{2}$, the users first input the linear string "x2 + 3/2". The rules of colloquial-style linear string set the key letters (or words) linearly corresponding to the symbols for the elements of a mathematical expression in the order they are read or spoken [6]. It is unnecessary to enter signs that are not displayed, such as the power sign and the parentheses as a delimiter for the numerator. Thereafter, a list of candidates is displayed as system prediction proposals as in Fig. 1. After that, they simply choose the desired expression from the list. Finished mathematical expressions are output in formats such as LaTeX, MathML, PNG, JPEG, EPS, Maxima, Maple, and Mathematica.

MathTOUCH enables users to input almost any mathematical expression dealt with in the general categories of mathematics from junior high school level to university level without having to learn a complex language such as LaTeX. Some examples for linear strings for MathTOUCH and LaTeX-form are shown in Table 1. For example, the linear string for $\cos^2\theta$ is denoted by "cos2t." However, the linear string of the expressions $\cos 2\theta$, $\cos^2 t$ and $\cos 2t$ are also denoted by "cos2t." Hence, there are some ambiguities in our linear string rules.

To address this shortcoming on such obscure rules, we have proposed a predictive algorithm to convert an linear string into the most suitable mathematical expressions using machine learning through a data set consisting of 4000 formulae [6].

Our prior research shows that MathTOUCH allows approximately 1.2–1.6 times faster task times than the standard interfaces. It shows higher satisfaction with regards to math input usability than the standard interfaces [5].

The results of our evaluation show that the prediction accuracy for the top ten ranking of our method is 85.2% [6].

2.2 Entering Mathematical Expressions

We explain the mathematical input process of MathTOUCH by using the case of the equation $y = x^2 \sin x$ which is illustrated in Fig. 2. First, users input a colloquial-style linear string for the desired mathematical expression. Then, a list of prediction proposals is displayed in a two-dimensional mathematical notation by using our proposed predictive algorithm through a machine learning. In this case, the linear string is "y = x2sinx" and the user then hits the top of prediction proposals in the list. After all the elements are interactively chosen, the desired expression is formed. Finally, the complete mathematical expression is outputted in the desired format.

MathTOUCH was developed using JavaScript and can be integrated into the other systems.

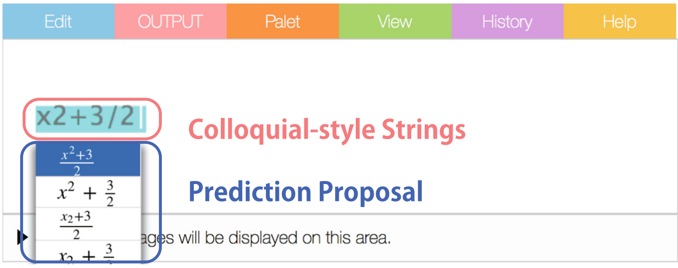

Fig. 1. MathTOUCH: math input interface.

Table 1. Examples of colloquial-style linear strings.

Mathematical expression	MathTOUCH	LaTeX-form
$x^2 + 3x + 2$	x2 + 3x + 2	`x^{2}+3x+2`
$\frac{2}{5}$	2/5	`\frac{2}{5}`
$\sqrt{3}$	root3	`\sqrt {3}`
$\cos^2 \theta$	cos2t	`\cos^{2}\theta`
$\log_{10} x$	log10x	`\log_{10}x`
$\sum_{k=1}^{n} a_k$	sumk = 1nak	`\sum_{k=1}^{n}a_{k}`
$\int_a^b f(x)dx$	intabf(x)dx	`\int_{a}^{b}f\left(x\right)dx`

3 Proposed Intelligent Editor

We have developed an editor for authoring educational materials in mathematics e-learning systems that enables users to embed any mathematical expression into the text using MathTOUCH. In this section, we describe a specification

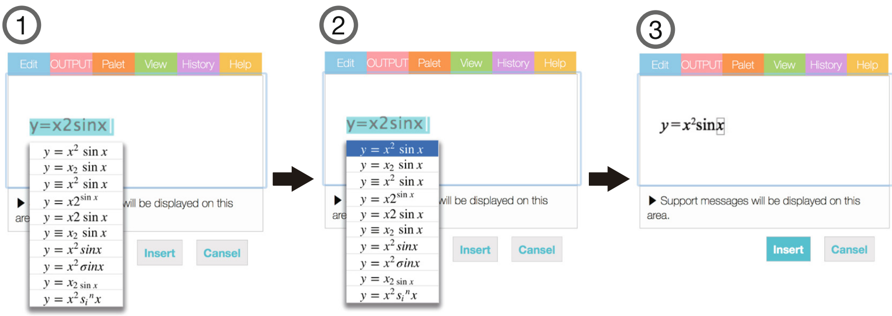

Fig. 2. Mathematical input process on MathTOUCH.

of a proposed intelligent editor and how to edit educational materials including mathematical expressions using our editor.

3.1 System Specification

This editor was created in JavaScript (HTML5) to make it compatible with other e-assessment systems.

Figure 3 represents our proposed intelligent editor window and their editing functions in the menu palettes. This editor has functions like other common HTML editors such as the ability to change font size, font color, and inserting images. All functions are available from buttons arranged at the top of the editor window. Users are able to insert any mathematical expression by calling MathTOUCH from the insert equation button (Fig. 3, No. 23). The documents inside of the entry area in Fig. 3 are an example of a calculus question for an e-assessment system.

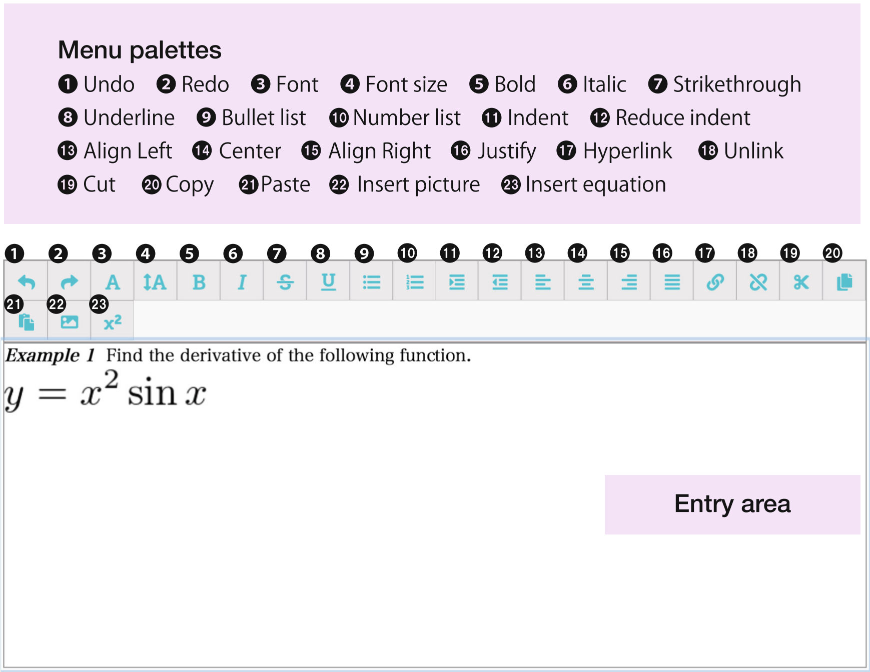

Fig. 3. Proposed intelligent editor.

3.2 Interaction Design

In this section, we explain the editing process of this editor. Figure 4 represents an example of authoring a question as in Fig. 3. First, the teacher inputs the quiz or question statement in the editing area. The MathTOUCH editor (the intelligent-type mathematical input interface), is available whenever it is called from the pop-up window using the insert equation button in the functional icon pallet (Fig. 4). In this case, in Fig. 4, the teacher inputted the text statement for a calculus question in the first line and called MathTOUCH from the insert equation button. After formatting the desired mathematical expression by MathTOUCH as mentioned in Sect. 2, the two-dimensional mathematical expression is embedded into the editing text at the cursor point in the second line of the entry area.

Therefore, it is easy to imagine how the questions are displayed on the e-learning system. Moreover, the embedded mathematical expressions on this editor are amendable by calling the MathTOUCH window again.

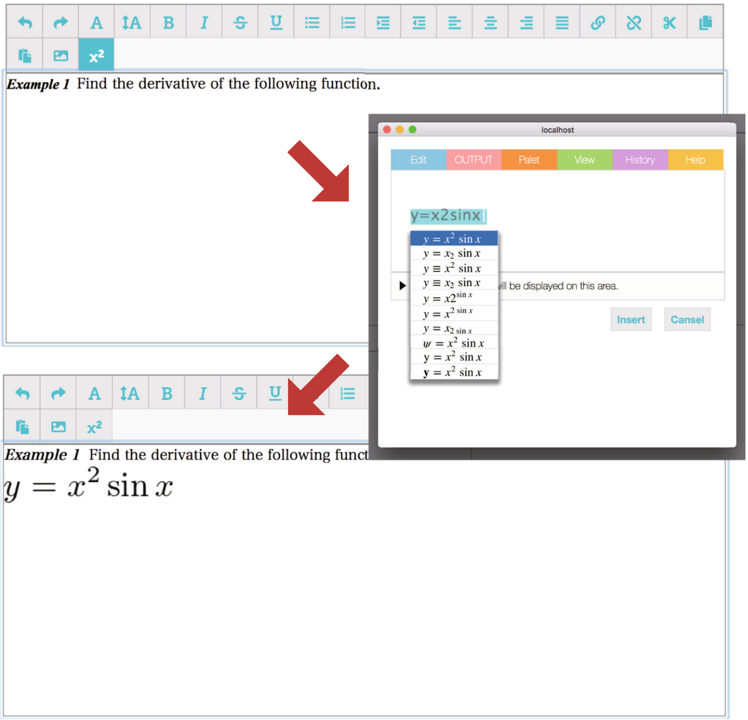

Fig. 4. Example of authoring a mathematical question on our proposed editor.

4 Conclusion and Future Work

In this paper, we proposed an intelligent editor for authoring educational materials in mathematics e-learning systems by implementing MathTOUCH. MathTOUCH is an intelligent-type mathematical input interface that enables users to insert desired mathematical expressions into the text editor in a two-dimensional mathematical notation using predictive conversion from colloquial-style strings through a machine learning algorithm. The proposed intelligent editor enables teachers to embed their desired equations and/or formulae into any point of a mathematical materials. Especially, they are able to imagine how the authored materials consisting of mathematical expressions are displayed on e-learning systems and to amend all the embedded mathematical expressions. Therefore, the workload of authoring educational materials for teachers would be reduced.

The most important avenues for future research are evaluating the editor and implementing it in MeLQS systems that are created with Moodle.

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References

1. Sangwin, C.: Computer Aided Assessment of Mathematics. Oxford University Press, Oxford (2013)
2. Maple T.A.: Online Assessment System for STEM Courses 2013 Maplesoft. https://www.maplesoft.com/products/mapleta/
3. Osaka Prefecture University (2018) MATH ON WEB: Learning College Mathematics by web Mathematica. http://www.las.osakafu-u.ac.jp/lecture/math/MathOnWeb/
4. Fukui, T.: An intelligent method of interactive user interface for digitalized mathematical expressions (in Japanese). RIMS Kokyuroku **1780**, 160–171 (2012)
5. Shirai, S., Fukui, T.: MathTOUCH: mathematical input interface for e-assessment systems. MSOR Connect. **15**(2), 70–75 (2016)
6. Fukui, T., Shirai, S.: Predictive algorithm for converting linear strings to general mathematical formulae. In: Yamamoto, S. (ed.) HIMI 2017. LNCS, vol. 10274, pp. 15–28. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-58524-6_2
7. Kawazoe, M., Yoshitomi, K., Nakahara, T., Nakamura, Y., Fukui, T., Shirai, S., Kato, K., Taniguchi, T.: MeLQS: mathematics e-learning questions specification - a common base for sharing questions among different systems. In: Proceedings of the International Workshop on Mathematical Education for Non-Mathematics Students Developing Advanced Mathematical Literacy, pp. 123–126 (2018)
8. Pollanen, M., Hooper, J., Cater, B., Kang, S.: A tablet-compatible web-interface for mathematical collaboration. In: Hong, H., Yap, C. (eds.) ICMS 2014. LNCS, vol. 8592, pp. 614–620. Springer, Heidelberg (2014). https://doi.org/10.1007/978-3-662-44199-2_92
9. Pollanen, M., Wisniewski, T., Yu, X.: XPRESS: a novice interface for the real-time communication of mathematical expressions. In: Proceedings of the Workshop on Mathematical User Interfaces (2007)