E-learning system with Computer Algebra based on JavaScript programming language

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Abstract

Usually, e-learning system provides multiple choice questions and students choose the correct answer. However, some e-leaning systems, such as moodle with STACK plugin, are equipped with computer algebra systems and can deal with mathematical expressions. Such e-learning system let users input an answer directly in the form of mathematical expressions, hence is more friendly to the users.

One of the problems in those systems is that they often requires a special web server that has computer algebra systems installed, which is not an easy condition to elementary, junior, and senior high schools. This prevents classroom teachers from creating their own e-learning materials.

In this paper, we present a web-based e-learning system which can deal with mathematical expressions. Our system is constructed with JavaScript programming language, and only requires a web server with PHP support (database and standalone computer algebra system are unnecessary). More concretely, our e-learning system has the following features; (1) It contains computer algebra JavaScript library, and can deal with mathematical expressions. (2) It only requires a web server with PHP support (database and standalone computer algebra system are unnecessary). (3) It runs on standard browsers such as Google Chrome, Firefox and Opera, and can be used on PCs, smartphones, tablets. (4) It has editing functions itself, and a new e-learning material can be created on browsers.

The above features make it easy for classroom teachers to create their own e-learning materials. We illustrate how to create e-learning materials and give some examples created by our system.

1 Introduction

Recent technological developments has profound impact on effects on various fields of our society. Among the many area affected by the developments, this paper focuses on e-learning,

which we define as courses that are specifically delivered via the internet to somewhere other than the classroom where the teacher is teaching.

As is well-known, e-learning has a lot of advantages and been proven to be a successful method of training. For example, students can take the class from any location with internet access without any transportation fees. Moreover they can learn at their own pace.

One of the most suitable subjects for e-learning is mathematics. Because, to get good at mathematics, students need training and exercises, solving many mathematical problems, and e-learning is well-suited for such training.

Usually, e-learning system provides multiple choice questions and students choose the correct answer. However, some e-learning system for mathematics contain a computer algebra system, which enables them to treat mathematical expressions. In these systems, students can input mathematical expressions directly. Some of the examples of such system are Maple T.A. with computer algebra system maple, WebMathematica with computer algebra system Mathematica and STACK with computer algebra system Maxima. Since those systems can deal with mathematical expressions, users can input an answer directly in the form of mathematical expressions, hence is more friendly to the users.

One of the problems in those systems is that they often requires web servers that have computer algebra systems installed, which is not an easy condition to elementary, junior, and senior high schools. This prevents classroom teachers from creating their own e-learning materials.

In this paper, we present a web-based e-learning system which can deal with mathematical expressions. Our system is constructed with JavaScript programming language, and only requires a web server with PHP support (a standalone compute algebra system is unnecessary). Moreover, it has editing functions itself, and a new e-learning material can be created on browsers (it runs on standard browsers such as Google Chrome, Firefox and Opera, and can be used on PCs, smartphones, tablets). Those features make it easy for classroom teachers to create their own e-learning materials.

In the rest of the paper, we will describe our system and illustrate how to create and use e-learning materials with some examples.

2 JavaScript and libraries used in the system

2.1 JavaScript

As is well-known, JavaScript is an interpreted programming language with object-oriented capabilities. JavaScript is included in or referenced by an HTML document for the code to be interpreted by the browser. It means that a JavaScript program can be executed any IT device such as PC, tablet and smartphone, if it is equipped with a major web browser such as Google Chrome, Firefox, Edge, Internet Explore, Safari and Opera. It also means that a web page need not be a static HTML, but can include programs that interact with the user, control the browser, and dynamically create HTML content.

Recently, JavaScript becomes one of the most popular programming language and is quickly surpassing the popularity of not only other Web languages such as PHP, but even traditional back-end programming languages such as Java, at least according to the results of the latest annual survey from Stack Overflow, the popular question-and-answer site for developers and weekend hackers (see [3] for details). Based on this increase of the popularity, a lot of JavaScript
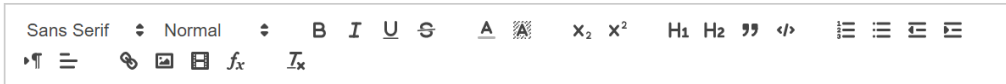
Figure 1: Quill editor menu

libraries are being developed, and almost all JavaScript libraries are released under either a copy-center or copyleft license to ensure license-free distribution, usage, and modification.

2.2 Algebrite

Algebrite is, in short, a computer algebra system in JavaScript which can be used as JavaScript library for symbolic computation (see [4] for details). Algebrite has the following characteristics;

- Algebrite has all basic functions of computer algebra system, arbitrary-precision arithmetic, polynomial and rational function computation, differentiation and integration of functions, simplification, matrix and tensor computations, and so on.

- Algebrite only depends on big integer package BigInteger.js and is lightweight (program size is less than 700Kb).

- Algebrite does not need connection to servers or another back-end computer algebra system.

- Algebrite is written in JavaScript and can be embedded in other applications and extended with custom functions.

- Algebrite is MIT-Licensed and free.

To execute a command of Algebrite from JavaScript, just call JavaScript function 'Algebrite.run(cmd)' where 'cmd' is a command of Algebrite to be executed. For example, to compute 'x+x' (which is 2x), we call function Algebrite('x+x'), which returns string '2x'. The following are some sample commands from Algebrite official homepage [4].

```
Algebrite.run('13579/99999 + 13580/100000') -> 135794321/499995000

Algebrite.run('simplify(a*b+a*c)') -> a (b + c)

Algebrite.run('integral(x^2)') -> 1/3 x^3
```

2.3 Quill

Quill is a free, open source WYSIWYG (what you can see is what you get) editor written in JavaScript which has the following characteristics (see [5] for details);

- Quill editor enables us to create a menu on a web browser as in Figure 1. The menu can be used just as the menu of a word processor such as 'Word', and we can write decorated sentences and figures on the web browser.

- With the menu created by Quill editor, we can input mathematical expressions beautifully in Latex-syntax.

- Quill editor is highly customizable and fits to a wide variety of need.

- Quill editor supports and works on all modern browsers on PCs, tablets and smartphones, and is BSD 3-clause.

The menu in Figure 1 is also customizable, and it is possible to hide the menu. In our system, we hide the menu when students use the e-learning materials.

2.4 Other JavaScript library

We also use JavaScript library 'jQuery' for DOM manipulation and Ajax, and 'sha1.js' for password management.

3 How to use the system

Our system has two modes, one is for the teacher who creates an e-learning material by our system, and the other is for students who use the e-learning material created. We call former mode 'editor mode' and latter mode 'user mode'.

Let us show how to use the system. First, we will show how to make an e-learning material (online test) in our system. To make an e-learning material, we start up our system in editor mode. More concretely, we open the template file of our system with web browser Google Chrome. The screen shot of the template file opened with Google Chrome is in Figure 2.

As an example, let us make an e-learning material for differentiation of functions in Calculus. Figure 3 shows screen shot of a completed e-learning material in editor mode.

Let us explain the completed material one by one. Explanation part contains a description of learning items, and we enter the definition of the derivative of a function with Quill editor.

The area below 'Problem 1' is problem part and contains an exercise. In this e-learning material, we will present the following exercise to the student, where a, b and c are random integers between 2 and 10;

Problem 1. Compute the derivative $f'(x)$ of the following function $f(x)$

$$f(x) = ax^2 + bx + c$$

To generate random numbers a, b and c, we enter a JavaScript code on the textbox named 'JavaScript (1)' (JavaScript code in the textbox is executed when the system shows the problem to students and can be used to generate random numbers). Function `ranint(2,10)` in the textbox is the JavaScript function that generated a random integer between 2 to 10.

Under the JavaScript code, we key in the above "Problem 1" where [[a]], [[b]] and [[c]] denote variable a, b and c in the JavaScript code.

On the textbox under 'correct answer', we enter the correct answer to the problem (again [a]], [[b]] and [[c]] denote variable a, b and c in the JavaScript code).

Template file of our system consists of one explanation part and five problem part 'Problem 1' ~ 'Problem 5'. Hence, we need to continue entering problems until all five problem parts are

Admin menu : [Go to user mode] [Save]

User name :

Explanation

Sans Serif ▲ Normal ▲ **B** *I* U S A A x₂ x² H₁ H₂ ❞ </>
☰ ☰ ☰ ☰ ▸¶ ☰ ⌗ ⌗ ⌗ ⌗ fₓ Tₓ

Compose an epic...

The number of times	Test score	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5

[Scoring] Test score :

Problem 1

Javascript (1)

Sans Serif ▲ Normal ▲ **B** *I* U S A A x₂ x² H₁ H₂ ❞ </>
☰ ☰ ☰ ☰ ▸¶ ☰ ⌗ ⌗ ⌗ ⌗ fₓ Tₓ

Compose an epic...

Correct answer:

Answer:

Figure 2: Screen shot of the template file of our system in editor mode

Admin menu : [Go to user mode] [Save]

User name : yuzu

Explanation

Sans Serif ⬍	Normal ⬍	**B** *I* <u>U</u> ~~S~~	A A̲	X₂ X²	H₁ H₂ " </>
☰ ☰ ☲ ☲	▸¶ ☰	🔗 🖼 🎞 *fx*	T̶ₓ		

The derivative $f'(x)$ of a function $f(x)$ is defined by
$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} \ .$$

The number of times	Test score	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5

[Scoring] Test score :

Problem 1

Javascript (1)

```
a=ranint(2,10);
b=ranint(2,10);
c=ranint(2,10);
```

Sans Serif ⬍	Normal ⬍	**B** *I* <u>U</u> ~~S~~	A A̲	X₂ X²	H₁ H₂ " </>
☰ ☰ ☲ ☲	▸¶ ☰	🔗 🖼 🎞 *fx*	T̶ₓ		

Compute the derivative $f'(x)$ of the following function $f(x)$
$$f(x) = [[a]]x^2 + [[b]]x + [[c]]$$

Correct answer:

```
2*[[a]]*x+[[b]]
```

Answer:

Figure 3: Screen shot of a completed e-learning material in editor mode

Figure 4: Screen shot of an e-learning material in user mode

completed. After completing all the problem parts, we click 'save' button in Figure 1 to save the completed e-learning material. Then, the completed e-learning material will be downloaded and the creation of an e-learning material is finished. This is how to create an e-learning material by our system.

Next, we will explain how to use an e-learning material completed. First, we have to upload the material to the web server and let students access the material.

When accessed by students, the e-learning material shows its contents in user mode. Figure 4 shows what the e-learning material looks like in user mode. As the figure shows, variables a, b and c is replaced by random numbers generated by the JavaScript code, and editing menu of Quill is hidden. Students are required to input the answer to each exercise in Problem 1 ∼ 5.

Having answered to all problems, students click 'scoring' button to score their answers. Then the system (more concretely computer algebra system 'Algebrite') returns the scoring results as in Figure 5, showing the correct answer where student's answer is incorrect.

Explanation

The derivative $f'(x)$ of a function $f(x)$ is defined by
$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h} \ .$$

The number of times	Test score	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
1	60	✕	◯	◯	◯	✕

[Next exercise set] Test score :   60

Problem 1

Compute the derivative $f'(x)$ of the following function $f(x)$
$$f(x) = 7x^2 + 8x + 4$$

Answer :   Incorrect. Correct answer is 14 x + 8.

```
10x+4
```

Problem 2

Compute the derivative $f'(x)$ of the following function $f(x)$
$$f(x) = 9x^2 + 3x + 6$$

Answer :   Correct

```
18x+3
```

Figure 5: Screen shot of an e-learning material in user mode

If the scoring result is above certain predetermined threshold score (say 80 of 100 points) then 'submit the result' button appears and the student can submit his or her test result. If not, the student is required to clicks button 'Next exercise set' in Figure 5, which presents another set of exercises with different random numbers a, b and c. This repeats until the student gets the test score that exceeds the threshold score.

When students submit their scoring results, not only their score but also their answers and correct answers are submitted and recorded on the web server. The records are in CSV format, hence the teacher can check and analyze the result with a spreadsheet application such as Excel.

4   Features of our system

One of the most characteristic feature of our system is its capacity to treat mathematical expressions. Our e-learning system contains computer algebra system Algebrite and can treat mathematical expressions. This leads to the following advantages;

(a) Students can input mathematical expressions directly (it is more intuitive than multiple choice questions).

(b) Correct answers to problems can be computed by the system and we do not have to prepare the answers (in multiple choice questions, we need to prepare wrong and correct answers for the problem).

Usually, an e-learning system that can treat mathematical expressions requires a special web server. For example, moodle with STACK plugin requires a web server that has database, Moodle with STACK plugin and computer algebra system Maxima (see [1] [2] for details). It is not easy task to set up and maintain such web servers, and it may be difficult for especially primary, junior high and high schools.

Compared with such systems, configuration of our system is fairly simple. Basic function of the system is programmed in JavaScript language, and the system only requires a web servers with PHP support (even database is unnecessary). Hence, our system is easy to set up and use, especially for primary, junior high and high schools.

In addition to the above capacity to treat mathematical expressions, our system is equipped with following characteristics;

- The system works on browsers, hence it works on any IT devices such as PCs, tablets and smartphones without any additional installation of software components.

- Our system is composed of free and open-source software, hence any software license fee is unnecessary.

5   Future directions

Currently, we consider the following challenges as future works;

- In our system, data format is unique and there is no compatibility of the data. Hence, the e-learning material created by our system can not be used in other system, and the e-learning material created by other system can not be imported to our system. If there is

a data converter between data in our system and standard data format such as SCORM, it will be useful.

- Although our system is easy to set up compared with other systems, it still needs a web server with PHP support. This can be a burden on classroom teachers, and we want to make our e-learning system free from any web server.

6   Conclusion

Some e-learning systems are equipped with computer algebra systems and can treat mathematical expressions. Such systems allow students to input mathematical expressions directly, hence is more friendly to users. However, such systems often require standalone computer algebra systems and may be difficult to set up and maintain, especially for elementary, junior high and high schools.

This paper presented a new e-learning system that can treat mathematical expressions and only requires a web server with PHP support. The new e-learning system is programmed by JavaScript language, and has editing functions itself, which make it possible to create a new e-learning material on browsers (it runs on standard browsers such as Google Chrome, Firefox and Opera, and can be used on PCs, smartphones, tablets). We illustrated how to create and use a new e-learning materials by the new system.

Currently, we consider the following challenges as future work of the new system.

Since data format of the new system is unique, the e-learning material created by the new system can not be used in other system. Hence, a data converter between data in the new system and standard data format such as SCORM will be useful.

Although the new system is easy to set up compared with other systems, it still needs a web server with PHP support. We want to make the new system free from any web server in the future.

References

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