

From Electronical Questionnaires to Accessible Maths on Web

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Abstract

The authors of the proposal needed to ensure the accessibility of electronical questionnaires with mathematical expressions displayed as images. Any existing solution was not sufficient in 2014, so they came with their own javascript library which enabled blind students to change the type of maths expressions' text descriptions between LaTeX, Braille and Voice output mode. Later on, they innovated the library to be usable for any mathematical website and increased the number of supported mathematical elements.

1 Introduction of the Problem

In the end of the year 2013, we registered an interest of four blind students to study the course *Introduction to Logic* run by Faculty of Informatics of our university. When analyzing possible barriers we faced the following problem. All the course students are periodically tested by means of electronical questionnaires which include many mathematical expressions displayed as images. The questions are randomly selected and generated from large question sets (dozens of questions per one set) that are prepared by teachers of the course and stored in a database granted by *Masaryk University Information System*^{*} (IS MU). Therefore a certain student answers different questions than the others. The teacher of the course has to set up the concrete test's options, for example how many questions should be chosen, which sets of questions should be taken, how much time is granted for students to solve the test, which day(s) or week(s) should students pass them, etc.

When analyzing the questionnaires we came to the following results:

1. There is no time left to ensure the accessibility of a concrete test once it is generated. Having opened some questionnaire a student needs to solve it immediately, therefore it is necessary to guarantee the test's accessibility beforehand. Despite the only small amount of questions is randomly selected to be answered by a blind student, all the questions in all the question sets should be prepared regarding their accessibility.

^{*} The Masaryk University Information System "hosts numerous applications utilized for managing study-related records, e-learning tools and those facilitating communication inside the University. It is used by 30,000 users (of the total of 44,000 students and staff members) a day." (10)

2. When preparing questions a teacher writes any mathematical expression in LaTeX and closes it into special tags `<m>`, `</m>`. The system then uses a tool to convert the LaTeX code into the image. The LaTeX representation of the expression is put as an alternative description of the image.
3. Any questionnaire offers an optional text field to add a teacher's commentary in front of all the questions. It may also contain an html code or a link to some javascript functions which are executed immediately after the page is generated for a student.

We reached an opinion that the LaTeX alternative description text is not a sufficient support for blind users of the course questionnaires. At first, our four blind students were not familiar with LaTeX. Additionally, it is very difficult to understand the structure of complex mathematical expressions written in LaTeX.

2 State of the Art

We did not have so much time to research all the possibilities that can help us with the problem. The course started just after two months we had got to know the blind students are registered. We knew about the Javascript library *MathJax* (1) which

1. can display a mathematical content visually and in a high-quality level (not as bitmaps),
2. offers more formats of input such as MathML, TeX, or ASCII math , and
3. gives visually impaired users some tools to read maths in an accessible way:
 - a. to scale all the mathematical content on the page with an optional zoom factor,
 - b. to zoom in only the mathematical expression which is under the cursor,
 - c. to use the *Math Player* plug-in (2) which generates a speech output of maths.

The MathJax library and the MathPlayer plug-in are localized in Czech language. Together, these tools are a great support for blind and partially sighted readers of mathematical content on any website. We didn't find any better solution of our problem.

Despite all the helpful features of MathJax, there were unfortunately two serious disadvantages of MathPlayer:

1. The four blind students were studying the course Introduction to Logic during the first half of 2014. Three of them were using *MS Windows* operating system and MS Internet Explorer 11. MathPlayer 3.0 was released in June 2013 and supported Czech speech output, unfortunately worked only with the old version IE 9. People from Design Science commented the situation concerning MathPlayer 3.0: "Not all features are implemented in IE10 because of IE10 bugs. Unfortunately we can't support MathPlayer on Windows 8 because IE10 is required." (3) We encountered the same problem with IE 11 which was released in the end of 2013. If our blind students wanted to use MathPlayer 3.0, the newest version of the plug-in at that time, they had to downgrade to IE 9 because any other web browser was not compatible.
2. MathPlayer 3.0 didn't provide Czech users with a braille output according to the Czech Six Dot Braille Code for typing mathematics. Two of the course students were totally blind and strongly preferred to read mathematics in braille. We understood their preference. When using the speech output it is very difficult to perceive all the details of a complex mathematical formulae and to create a mental idea of its structure and relations between its elements.

3 Solution

Finally, because of these two reasons, we came to the decision to create a new javascript library — *Limpet*. Because of the lack of time we included the only symbols appearing at the questionnaires of the course Introduction to Logic. We prepared a list of mathematical elements with their LaTeX, braille and textual representation. The symbols were chosen mostly from the Propositional calculus, Predicate logic and Set theory. We designed the library to work with IS MU questionnaires.

After loading with the Limpet library the test itself looks the same as before. There are two additional small buttons (standard html form elements) at the top-right corner of the questionnaire which enable blind users to set up displaying of mathematical expressions. They can

1. change the mode of alternative text: LaTeX, Braille, Voice, and
2. replace images of mathematical expressions by their descriptions in the selected mode.

These two elements are not very visible on the page and do not disturb sighted students. The first button enables blind users to read math expressions on refreshable braille displays (the Braille mode) or follow their textual representation by speech output (the Voice mode). You can see an example of a questionnaire with both buttons on the Figure 1.

[Braille -> Voice](#)
[Hide Images](#)

Průběžně uložit

1. Which of these formulas represents the same logical function as given formula?

$p \Rightarrow (\neg q \Rightarrow p)$

☐ $(\neg q \vee p) \vee (q \wedge \neg p)$
☐ $q \wedge \neg p$
☐ $(p \wedge \neg q) \vee (\neg q \wedge p)$

* Nechci odpovídat. Chci [vymazat](#), co jsem zaškrtl u této otázky.

2. For existential \exists and universal \forall quantifier it holds:

☐ $\forall x P(x)$ is equivalent with $\exists x (\neg P(x))$
☐ $\neg(\forall x P(x))$ is equivalent with $\exists x (\neg P(x))$
☐ $\neg(\forall x P(x))$ is equivalent with $\neg(\exists x \neg P(x))$

* Nechci odpovídat. Chci [vymazat](#), co jsem zaškrtl u této otázky.

3. Which of these sets of formulas is not unsatisfiable?

☐ $\{s \wedge \neg q, t \Rightarrow (q \vee p), \neg(p \vee \neg r), (p \vee \neg q) \Rightarrow (r \Leftrightarrow (s \wedge \neg t))\}$
☐ $\{r \wedge \neg s, \neg t \Rightarrow \neg r, (r \Leftrightarrow (s \wedge \neg t)) \vee (\neg p \wedge q) \wedge (\neg q \vee \neg r)\}$
☐ $\{(\neg p \Rightarrow \neg q) \Rightarrow (r \Leftrightarrow (s \wedge \neg t)), p \wedge q, s \vee \neg q, r \Rightarrow \neg p, \neg t\}$

* Nechci odpovídat. Chci [vymazat](#), co jsem zaškrtl u této otázky.

Průběžně uložit

Uložit a **vyhodnotit** moje odpovědi

Figure 1: An example of some IS MU questionnaire with two buttons at the top-right corner, the first one to switch the alternative text version, the second one to hide the pictures of mathematical expressions; see below the braille transcription of the set of logical formulae.

It was very easy to introduce blind students and teachers with the library. The teachers were asked to put four lines of html code (a link to the library) into the optional text field of any questionnaire they wanted to “send” students. The blind students were instructed about the button and where they can find it. We had a positive feedback from them, the library worked well and there were no problems with Jaws and NVDA, the two screenreaders our blind students used.

4 Further Development

The course was finished in the end of June 2014. All the four blind students passed it successfully. After that we decided to improve the library. We used two main sources, *Lambda* (4) and *Chatty Infty* (5) database of symbols, and increased the number of supported mathematical elements up to 200 symbols. We also modified the source code of the library so it can be used to display a mathematical content of any website (not only IS MU questionnaires) in an accessible way. We used *dvipng: A DVI-to-PNG converter* (6) and installed it on the web server of Teiresiás Centre. Our colleague then designed a script translating LaTeX sample into DVI file and performing its conversion to PNG format by dvipng. The library Limpet calls the script from our web server to generate images.

Let’s see the example of the html code representing the expression “the root of the fraction five over $x + 1$ ”:

```
<img class="math" alt="f(x) = \sqrt{\frac{5}{x+1}}">
```

5 Method of Testing

We asked four blind students of Masaryk University to perform a double test of the library new version’s functionality. Two of them passed the course Introduction to Logic so they had already known the Limpet library. The students selected the most common browsers and screenreaders used by blind users of computers (see the Table 1) and tested

1. correct displaying of mathematics on refreshable braille displays according to the Czech braille rules,
2. voice output comprehensibility,
3. if the library is user friendly and accessible.

They worked with two testing websites full of mathematical expressions and two sample documents[†] with the same content as the websites. After the first test we reflected the feedback of the testers concerning the library's functionality and

1. revised all the bugs,
2. added new elements, approximately 100 mathematical symbols and structures,
3. improved manipulation with the library, and
4. innovated the method of rendering a visual representation of expressions.

[†] The sample MS Word documents were prepared in two versions: BlindMoose (9) (the Czech add-in for blind users who work with mathematics in braille) and MathType (one of the blind testers didn’t know the Czech Braille Six Dot Rules, he preferred to read mathematics in LaTeX)

Our effort resulted in creating the second version of the library which was again tested by the same four blind students. They gave us a valuable feedback so we were able to finish designing of the library, and conclude which tools (browsers, screenreaders) are optimal to use: the browsers Mozilla Firefox or Internet Explorer together with the screenreaders Jaws or NVDA.

1st Test			
<i>Student</i>	<i>Operating System</i>	<i>Internet Browser</i>	<i>Screenreader</i>
Student 1	MS Windows 7	Firefox 35.0.1, IE 11	NVDA 2014.2, Jaws 15.0.11024
Student 1	Ubuntu 14.04	Firefox 35.0.1	Orca 3.15.4
Student 1	Android 4.3	Firefox 35	Talkback 4.0.4 Beta
Student 2	MS Windows 7	Firefox 36, IE 11, Google Chrome 37	WinMonitor 2.1.10 [‡]
Student 3	MS Windows 7	Firefox 35.0.1, IE 11	NVDA 2015.1
Student 3	Arch Linux 3.18.5	Firefox 35.0.1	Orca 3.15.5
Student 4	MS Windows 7	Firefox 35, IE 11, Google Chrome 40	Jaws 14
2nd Test			
<i>Student</i>	<i>Operating System</i>	<i>Internet Browser</i>	<i>Screenreader</i>
Student 1	MS Windows 7	Firefox 37.0.1, IE 11	NVDA 2015.1, Jaws 15.0.11024
Student 1	Ubuntu 14.04	Firefox 37.0.1	Orca 3.15.4
Student 1	Android 4.3, Android 5.0.2	Firefox 37	Talkback 4.1.0.5 Beta
Student 2	MS Windows 7	Firefox 36, IE 11	WinMonitor 2.1.10
Student 3	MS Windows 7	Firefox 36.0, IE 11	NVDA 2015.1
Student 3	Arch Linux 3.19.3	Firefox 37.0.1	Orca 3.17.0-pre
Student 4	MS Windows 7	Firefox 37.0.1, IE 11, Google Chrome 41.0.2272.118	Jaws 14

Table 1: Summary of all the operating systems, internet browsers and screenreaders which were tested by four blind students of Masaryk University.

6 Conclusion

The library Limpet is now completed for Czech users. It enables to display accessible mathematical content on any website including questionnaires generated by Masaryk University Information System. We consider the library as a good alternative to the Math Player plug-in[§].

In the end of the year 2015, we plan to make other improvements of the Limpet library:

1. to prepare the English version of the library,

[‡] WinMonitor is a Czech screenreader developed by the company ACE Design for only Czech blind users of a speech or braille output.

[§] After one year, Math Player's authors made a big step to spread the plug-in between users. They secured the Math Player's version 4 functionality with a free of use NVDA screenreader so the blind users can read mathematical documents in two most common browsers: Internet Explorer, Firefox. (3)

2. to create a tool which takes MS Word file with mathematical expressions in *MathType* (7) as an input and convert it to the accessible website which can be supported by our library.

We hope to demonstrate these new features during the DEIMS conference in February 2016. To find more information see the websites of the Limpet library (8).

References

1. **The MathJax Consortium.** MathJax. [Online] <https://www.mathjax.org/>.
2. **Design Science.** MathPlayer. [Online] <http://www.dessci.com/en/products/mathplayer/>.
3. —. MathPlayer: Version History. [Online] [Cited: December 18, 2015.] <http://www.dessci.com/en/products/mathplayer/versionhistory.htm>.
4. **Nicotra, Giuseppe.** Lambda Project, Linear Access to Mathematic for Braille Device and Audio-synthesis. [Online] <http://www.lambdaproject.org/>.
5. **Infty Project.** Research Project on Mathematical Information Processing. [Online] <http://www.inftyproject.org/en/index.html>.
6. **Larsson, Jan-Aake.** CTAN: Package dvipng. [Online] <https://www.ctan.org/tex-archive/dviware/dvipng>.
7. **Design Science.** MathType 6.9. [Online] <http://www.dessci.com/en/products/MathType/>.
8. **Másilko, Lukáš and Nečas, Ondřej.** Limpet. [Online] <http://www.teiresias.muni.cz/limpet>.
9. **Nečas, Ondřej.** BlindMoose. [Online] <http://www.teiresias.muni.cz/science-research-and-development/development/bm?lang=en-GB>.
10. **Faculty of Informatics, Masaryk University.** More Information About Our System. [Online] [Cited: December 18, 2015.] http://is.muni.cz/nas_system/?lang=en.