Aspects of Mathematics Learning Objects Creation for Persons with Visual Disabilities

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In computer-assisted learning, a permanent concern is to create the learning objects, adapted to learners' level and skills which they will achieve. The problem becomes more complex when the users are people with disabilities, and this requires a different way of thinking and makes learning objects, in which the accessibility and usability are the priority. On the other hand the access of persons with visual disabilities to scientific content is limited and mathematics uses a specialized and highly formalized language, which makes it difficult to understand terms used in this field. This paper aims to present a solution for creating learning objects in mathematics for training persons with visual disabilities.
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1 Introduction

From the pedagogical and informatics point of view, the learning objects represent a new way of thinking educational material as being composed in educational units (for 10 to 15 minutes), which can be reused in different learning environments, similar to object-oriented programming principle [1].

Learning Object content for people with visual disabilities should be presented differently or using different channels so that their meaning to be understand by users. Sound is also incorporated into the learning objects to help visually impaired or blind people.

Learning objects have certain characteristics that must be taken into account when they are created. Among these are noticed:

- independence in terms the way to use the learning objects;
- interactive character of the interaction with the content (are activated the knowledge on which the student had previously acquired);
- they are adaptable to different learning styles;
- composability, which by reusability permits grouping them into large and complex collections of objects to create a new lesson;
- decomposability namely, the possibility of a complex object to be decomposed into elementary objects and rearranged according to teacher's preferences [2];
- granularity, which refers to the complexity of the learning objects and the extent to which objects can be decomposed into smaller objects;
- the possibility of storage them into repositories of learning objects, identifiable by metadata;
- interoperability, which eliminates dependency by a platform so that they can be used on different systems.

The need to provide an individualized learning requires the creation of reusable learning objects [3]. These objects, regardless of how are used, as stand alone or combined objects have several advantages, among which more important are:

- flexibility in use, allowing a quick coupling of created objects;
- easing of retrieval and management of content (ie filtering and selecting an only relevant content for a particular purpose), including the updating, provided by metadata that describe learning objects;
- adapting to requirements, through objects' modularity which allow to customizing and recombination objects to the level of granularity desired;
- interoperability with other systems and adapting to new requirements because of the objects approach;
- increase the value of content with each reuse and getting the complex learning objects.

In computer assisted learning for persons with disabilities the achievement of reusable learning objects compatible with assistive technologies enables educators to create lessons adapted to these users.

2 Particularities of learning objects in mathematics

Mathematics is an universal language of international communication, applicable in many areas of activity. While users with visual disabilities are able to access and manipulate textually math, they are excluded from viewing use of forms with semantic spacing, typically used for mathematical constructions. Therefore, an equation more or less simple is generally non accessible to the visually impaired user, because the information in this mathematical representation format are based on a visual and spatial context.
Efforts concerning the mathematics accessible both in terms of reading, writing and navigating through mathematical formulas, are made, the proof is the emergence of tools for converting Braille code from one format to another to be edited and rendered to blind persons, but each of these tools have their limits [4].
Mathematical language must be seen both in terms of meaning and notation used, the mathematical concept being regardless of the representation used. The most mathematical concepts are better explained using visual methods, but to convey the mathematical content to persons with disabilities are used other channels of communication i.e. audio and tactile [5].
An important aspect in mathematics' accessibility for persons with visual disabilities relates to the reading mathematical expressions. Each symbol from mathematical expression has a graphical representation, equational form, a textual representation, used by mathematical editors and textual form (obtained by using LaTeX and MathML equation editor), which underlies "the reading" mathematical expression [6] (Figure 1).

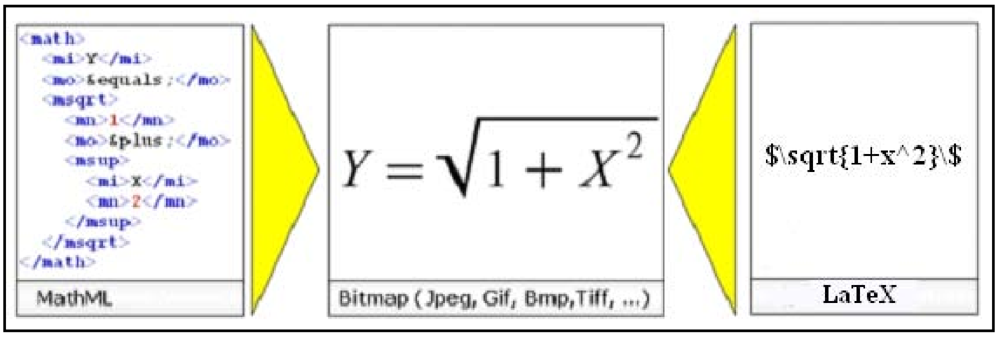

Fig. 1. Equational form of mathematical expression (graphical and textual)

LaTeX and MathML tools have been used to obtain the textual format. LaTeX is widely used in academic and commercial community and among other advantages it offers are the extensibility, which allowed the definition of new construction [7]. Because it is a language based on macros, LaTeX is configurable, many of the basic commands can be redefined or configured.
On the other hand, MathML is intended to facilitate the use and reuse of mathematical and scientific content on the Web and other applications such as computer algebra systems, editing of print and voice synthesis [8].
An example for reading a mathematical expression in Romanian it can be that from the textual format (Latex or MathML) text processing occurs, and the text obtained in the Romanian language should be used as input to the voice synthesizer (Figure 2).

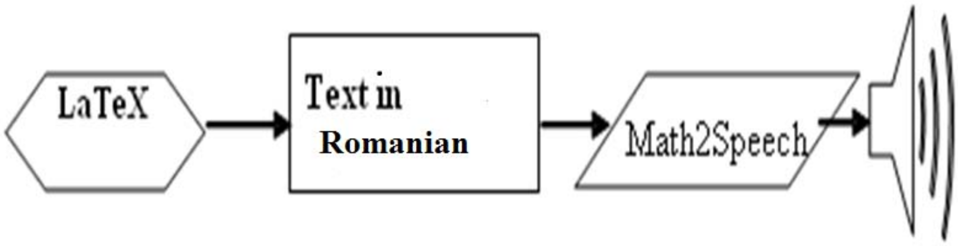

Fig. 2. Scheme of mathematical expression converting from LaTeX for reading with Math2Speech

To obtain a nearest approximation of natural speech is necessary to define a set of rules prosody. Three elements associated to prosody are the emphasis, intonation and rhythm, related to energy, frequency and temporal aspect of the voice signal [5].
The markers are very important in setting the prosody. They have a key role for determining the emphasis at TTS (Text To Speech) conversion.
The markers file is different from one domain to another. In a text, such as math, some markers lose their emphasized behavior from other fields. Thus, the word "if" serves as a marker (for focus) in colloquial language, while in a math text has a constructive element character of a particular type of sentence. The prosody markers used in determining the emphasis can be simple or compound [9] (**Table 1**).

Table 1. Examples for markers

Simple prosodic markers (in Romanian)	**Compound prosodic markers (in Romanian)**	**Specific markers or markers with high frequency in the field of mathematics (in Romanian)**
Dacă	Dacă şi numai dacă	Tinde la
Totuşi	Şi totuşi	Aparţine
Chiar	Chiar dacă	Oricare ar fi
Care	Dar care	Există
Însă	Însă şi	Inclus în

The rules for prosody refer to punctuation marks and markers. The breaks' level reproduces the prosodic group of words of an utterance by marking (at the end of each word) cohesion with the next word.
In vocal rendering of mathematics the prosody signs as the breaks (delay), raising the voice (when are successive compositions) have of great importance to eliminate the ambiguity in the understanding of mathematical expressions.
Handling of mathematics involves well defined tasks beyond simple understanding of a mathematical formula, this requires the ability to divide, copy, transform and maintain the referential access to different parts of formula.
All mathematical expressions - even the most complex, can be uniquely represented as a tree structure. This module is aimed at removing the ambiguity in understanding the mathematical expression by a person with visual disabilities.
The independent software products provide a range of facilities which allow their combination, but the possibility of developing environments of communication between them is difficult, and an integrated training environment is completely missing.

3 Achieving of mathematics learning objects for persons with visual disabilities

The achievement of mathematics learning objects for persons with visual disabilities is possible by developing applications which use the .NET technology with voice synthesizers to Romanian.

We made such application using Microsoft development environment Visual C # 2010 Express Edition, which by their classes collection facilitates the design of Web or Windows applications. This language works on the platform .NET as a user control.

The approach is based on components, respectively a component as a graphical equation editor builds the equational image, while providing textual description in Latex language and another component builds the text with pronunciation in Romanian and forwards it to the voice synthesizer. (Figure 3)

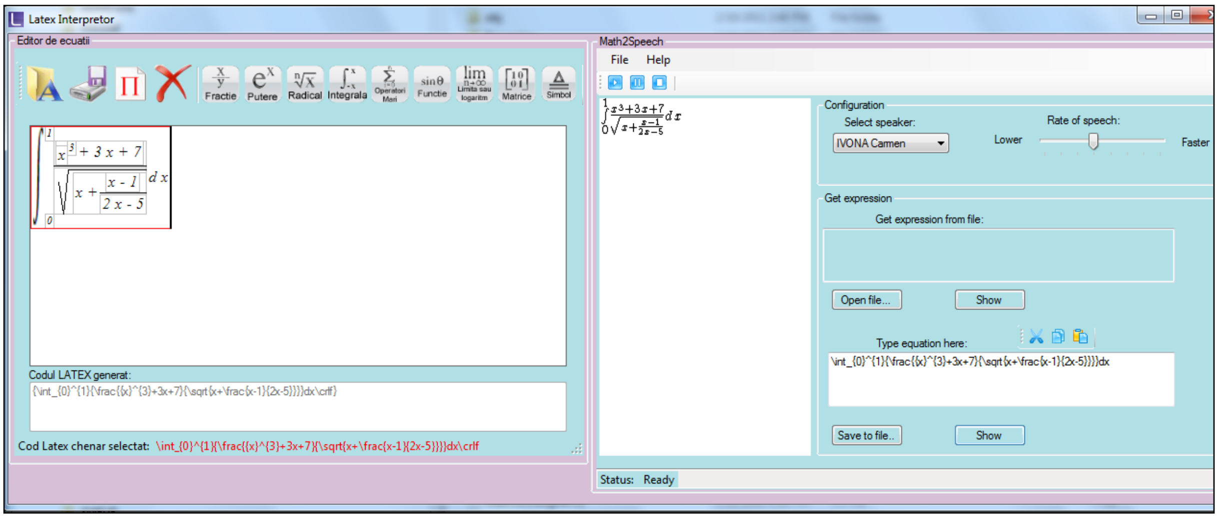

Fig. 3. Components approach in building of mathematics learning objects

The output of this control which consists in the LaTeX code of an expression constructed through an intuitive graphical interface, can be forwarded to another control, which validates the correctness of mathematical equation defined, represents in graphical mode the function defined in LaTeX code and reads this equation.

LaTeX elements have been implemented objectual. The objectual approach allows extending the functionality of control because for add a new LaTeX element type is adequate the derivation of an existing class and implementation of basic methods which defining the object's behavior. At these types of existing elements may be added the new items.

The application is based on the following entities:

• **Expresii.cs**- contains the necessary properties to control the opening and closing some components of mathematical expressions;

• **Formula.cs**- allows the selection of a whole formula, a formula already compiled and known by system for handling her through the user controls;

• **EditorEcuatii.cs**- contains the interaction with the equation editor enabling the election of category in which the graphic symbols related to an equation are fit.

Separation of the graphical interface by business side has led us to implement the identification algorithm and compiling of LaTex expressions in a separate program unit.

Although it can be saved also as image, the form accepted by system for equations introduced is scripting.

```
private void toolStripButton2_Click(object sender, EventArgs e)
        {
            saveFileDialog.Title = "Selectati locatia pentru salvarea fisierului
LATEX";
            saveFileDialog.FileName = "";
            DialogResult dg = saveFileDialog.ShowDialog();
if (dg == DialogResult.OK)
            {
string denumire = saveFileDialog.FileName;
                FileStream fisier = new FileStream(denumire, FileMode.Create,
FileAccess.Write);
                StreamWriter sw = new StreamWriter(fisier);
sw.Write(textBox1.Text);
sw.Close();
fisier.Close();
            }
```

The script version of the mathematical expression, introduced as equation, is written in a subset language of LaTex language, regarded as the best structured from existing description languages and with largest spread.
For the same entity, EditorEcuaţii.cs, is the management of the graphical space task for a symbol in an equation. When the object is more sophisticated (eg, matrix, stacked fractions, etc.) it has been defined a basic **ObiectComplexclass** from which they were derived private classes such as: *class Indice*, *Putere*, *Radical*, etc.
To each such object corresponding a rectangular graphical space, and to a complex object will correspond a reunion of individual spaces graphs (Figure 4 and Figure 5).

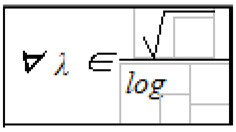

Fig. 4. Example for introducing items in containers

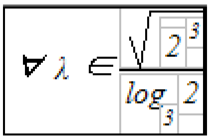

Fig. 5. Example of a complex object

Their relative positioning will lead to determining a rectangle that frame the entire complex object. The management of these combinations between graphic object and space graphical is implemented by source code **ObiectComplex.cs**.
The syntactic analyzer is based largely on the methods of the *String class*; its rules allow both writing script code, according to the graphic composition of equation by symbols, and the decomposition of a script LaTeX in components symbols for plotting graphic of equation automatically. At each symbol into an equation and thus to each LaTex subexpression will correspond to a specific pronunciation mode in Romanian.
The logic of expressions' composition or decomposition, expressed by the rules of syntactic analyzer, will be supplemented with rules of pronunciation and word order of Romanian language, used to the vocal rendering of the symbols from the structure of an equation.
Math2Speech.cs contains the code of forming the text used to reading the equation, as a control-user. Generally, the recursive composition of mathematical expressions is described by the source code, based on stack-discipline, thus the end of the sub-expression corresponds to a discharge of a frame from the stack.
"Coloring" the text will be delivered with

pauses, inflections of voice, etc.., according as the key points are reached in reading the expression, for example, the beginning of a new sub-expression, the closure of brackets which are not said or the need to increase the intelligibility of sounds produced.

These facilitate the assimilation of the mathematical expressions' sound rendering into a synthesized form, non-native.

Math2Speech.cs source code contains all possible combinations between LaTeX items and the text for the pronunciation of mathematical expressions in Romanian.

At some LaTeX items may correspond textual elliptical expressions, certain information being well-understood, for example, 2 order of radical, the closure brackets.

Also, these associations describe specific forms of audio rendering, for example, decimal logarithm, natural logarithm, which usually appear as alternatives of the general case (logarithm in base... of ......).

A significant part of the association table is occupied by the pronunciation of usual mathematical symbols and the Greek alphabet symbols.

Also, **Math2Speech** module deals with identifying and activating a voice synthesizer, used to read mathematical expressions.

The sound rendering is asynchronous, allowing the work in parallel for expressions' analysis which will be to read in the following sequence.

Other elements present here are those relating to the availability of the synthesizer, its moods, including progressive display of the text read in status bar.

If you do not want to use multiple user controls which interacting, **Math2Speech** module can start directly from a LaTex expression stored in a file or provided through the drag and drop mechanism.

```
        case '^': { FinalExpr += " la puterea "; index++; }; break;
        case '_': { FinalExpr += " indice "; index++; }; break;
        case '+': { FinalExpr += "plus "; index++; } break;
        case '-': { FinalExpr += " minus "; index++; } break;
        case ':': { FinalExpr += " împărţit "; index++; }; break;
        case '=':
           {
        if (ReadExpression[index + 1] == '\\' || ReadExpression[index-1]=='}')
            FinalExpr += "  ";// vg
            FinalExpr += "  egal "; index++;
           }; break;
        case '*': { FinalExpr += " ori "; index++; }; break;
        case '&': { FinalExpr += "  "; index++; } break;
        case '!': { FinalExpr += " factorial "; index++; } break;
        case '%': { FinalExpr += " la sută "; index++; } break;
        case '{':
        { if(ReadExpression[index-1]=='}')
                       FinalExpr+="  "; nr_pdeschise++;
        if (stiva_expresii != null)
                       paranteze_expresii('{', ref index);
                        FinalExpr += "  "; index++;
                   }; break;
```

The use of components technology allows defining, management and the interconnection of objects specific to mathematics, domain where the training is done [2].

In our application, C # was used, because it is a powerful object oriented language. The basic idea of object-oriented programming (Object Oriented Programming - OOP) is to create programs as a collection of objects, individual units of code that interact with each other. Basic principles of OOP, namely abstraction, encapsulation, polymorphism and inheritance, are retrieved within the application made, each entity in LATEX code being treated as a separate object. Using the inheritance, the basic object properties and methods are also transmitted to derived objects that share and extend the basic behavior without the need for its redefinition. Each object exposes an interface through which it interacts with other objects and can be achieved hierarchies of objects. A change in an object can be transmitted in a manner specific to each type of object.

In educational context, the transition from easy access to solving specific mathematics problem involves a series of difficulties related to the use of assistive technologies. This led the researchers to study the development of assistive environments for handling mathematics. The proposals advanced in this field are reflected in Stöger's work [10].

4 Conclusions

The idea underlying the achieving this control is that each element is an object, characterized by its position on screen (upper left corner) and its dimensions: width and height. Every element knows to be "self-managed" according to changes received from the outside and forwards the necessary changes to other objects.

The novelty of this control consists in objectual approach, each LaTeX element being is treated as a separate object. The elements were grouped into classes based on the functionality criterion. These are instantiated when the user wants to introduce a new symbol, character, function, etc.

The control achieved can be used in an e-learning application, for its mathematical modules. Combined with other controls or tools that perform different tasks using LaTeX strings, it helps to create some teaching-learning intelligent applications.

In mathematics, according to a non-visual representation of mathematical content, the mechanisms must be developed and used in order to offer the possibility to handle mathematical formulas by people with visual impairments. Therefore, the input and output methodologies and the facilities for interactive use of mathematics must be designed and developed for this group of users.

In computer-assisted learning, the components have the capacity coupling and enable their accessing as services, which leads to increasing potential of their use on e-learning platforms.

New information technologies allow the easy handling and composition of learning objects even by non specialists, teachers who create their lessons in an innovative way.

References

[1] N. Isăilă, "Particularities of educational objects in computer-assisted learning for persons with disabilities", *Annals of the „Constantin Brâncuşi" University of Târgu Jiu, Economy Series*, Issue 4, pp. 207- 214, 2010.

[2] I. Smeureanu, A. Reveiu and M. Dârdală, "Educational Technologies Based on Software Components", *Revista Informatică Economică, nr.3 (39)*, pp.40- 43, 2006.

[3] N. Friesen, "What are Educational Objects?"*Interactive Learning Environments*, Vol. 9, No. 3, Dec. 2001.

[4] A. Karshmer, G. Gupta and E. Pontelli, "Mathematics and Accessibility: a Survey", in *Proc.9th International Conference on Computers Helping People with Special Needs*, Vol. 3118, Paris, France, 2004, pp.664-669.

[5] N. Isăilă, "Accesibilizarea matematicii pentru persoane cu dizabilităţi vizuale", *Revista Română de Statistică*, Nr.3 Supliment, pp. 87- 90, 2010.

[6] I. Smeureanu andN. Isăilă, "Software pentru accesul persoanelor cu dizabilităţi la domeniul ştiinţific", *Revista Română de Interacţiune Om-Calculator*,Vol. 3 Număr special, pp.11-14, 2010.

[7] L. Lamport, *LaTeX: A document Preparation System, User's guide and Reference manual*", Addison-Wesley, Second Edition, 1994.

[8] D. Archambault, V. Mogco, "Canonical MathML to simplify conversion of mathml to braille mathematical notations", in *Proc. 10th International Conference on Computers Helping People with Special Needs*, vol. 4061 of LNCS, Linz, Austria, 2006, pp. 1191–1198.

[9] H. N. Teodorescu, "Îmbunătăţirea aspectelor prozodice în sinteza text-to-speech pentru limba română", *Revista de Politica Ştiinţei şi Scientometrie*, nr. special,

pp. 1-12, 2005.
[10] B. Stöger, M. Batuši, "Supporting blind students in navigation and manipulation of mathematical expressions: basic requirements and strategies", in *Proc. 10th International Conference on Computers Helping People with Special Needs*, vol. 4061 of LNCS, Linz, Austria, 2006, pp. 1235-1242.

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