Information and Technological Service for the Accompaniment of the Educational Process of People with Visual Impairments

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Abstract. The authors propose innovative approaches to the improvement of information technologies, methods and tools, which implement the formation of electronic library funds with specialized information products, integrating various types of information to provide information needs of people with disabilities. It is offered the new approaches to the formation of information resources and electronic libraries for this category of people promoting the processes of inclusive education. The processes of content preparation for providing convenient information and technological interaction of the blind with the information resources are analyzed, as well as the choice of the DAISY format (Digital Accessible Information System) for the creation of information products (audio books) with the use of flexible navigation mechanisms is substantiated. Moreover, it is proposed the classification of documents, which allows you to choose the levels of their structuring for effective transformation into DAISY format. The developed technology by authors is introduced and allows you to convert mathematical formulas of different complexity into a form that can be pronounced effectively by a synthesizer of the Ukrainian language.

The developed software and algorithmic means of sounding mathematical formulas in Ukrainian have given an opportunity to dub the Ukrainian technical texts with the help of a language synthesizer, fill DAISY books with technical content and convert the mathematical formulas into a text description. To convert the mathematical formulas presented in various versions of the MathML (presentation and semantic) records into an Ukrainian text, a special system of rules has been developed, which consists of rules for writing mathematical symbols, operators, general and specified expressions.

Keywords: DAISY format, electronic library, information resources for people with special needs.

1 Introduction

In the modern information society, a rethinking of traditional forms of information presentation is needed to the effective information support of the educational process of people with disabilities. The need of information resource formation in electronic libraries for this category of people has become especially relevant in connection with military actions taking place in Ukraine. Military men, who have been injured, after recovering, need to obtain "peaceful" occupations. But some of them got disabilities. This category of citizens needs special attention from the side of society. And learning processes require special approaches and specific information support, especially for visually impaired people.

The purpose of this paper is to present innovative methods and means of information and technological support of the educational process of people with visual impairment.

1.1 Analysis of the Research State

Increasingly, the need to expand the ability to provide information conveniently for people with special needs in different perceptual formats becomes relevant. The information technologies, methods and means that implement the resource formation of electronic libraries are developed and improved by specialized information products integrating different information to provide information needs of people with various physical disabilities. The research results on the information availability for blind users are reflected in the works of researchers such as Jeffrey P. Bigham, Meredith Ringel Morris, Yu Zhong, Samuel White [1] and others. Problems of creating information educational content are analyzed by Krapivenko A.V. [2] and Davydova E.V. [3] who investigate the problem of formation of effective multimedia information products. However, a comprehensive study of the peculiarities of the formation of information content for people with special needs has not been carried out yet.

1.2 Research Methods

The analysis of content preparation processes for the information and technological support of the educational process of the blind, conducted by the authors of the article, confirms the validity of the selection of the electronic book format for the blind, named DAISY format (Digital Accessible Information System). In this format books are convenient for the formation of an electronic library in terms of presentation of multimedia content. For the arrangement of the automated workplace of a blind user (AWP), modern special tools and technologies are used that provide convenient access of a blind user to information resources. To prepare the input data, the main provisions and methods of statistical analysis [4], classification [5, 6], and construction of decision trees are used, and to prepare the output audio content, it is used the method of transformation of the syntactic tree and the method of creating DAISY books in the Ukrainian language.

2 Electronic Libraries for People with Special Needs

Electronic libraries in the information society turn into convenient means for preserving information resources that provide information support and support for educational and social and communicative processes for people with special needs. An electronic library provides easy access to information resources online [7]. A characteristic set of basic features of an electronic library is its computer equipment, a digital way of recording information, technology of online access to information resources, etc. [8]. In addition to electronic documents, databases, user maps, hyperlink subsystems, other electronic information resources are the components of electronic libraries [9].

In this context, the information support of the educational process of people with special needs is the following:

- the use of specific forms of information representation for people with special needs, which in turn affects the features of the relevant information resource;
- the implementation of technological processes based on the algorithms of the information resource presentation created for each category of such users;
- the development of methodological recommendations for the information support implementation and information and technology support for the educational process of people with disabilities.

The term of electronic library for users with special needs means an information system designed to accumulate, structure and organize an array of electronic documents with an appropriate access system to provide a user with special needs with an integral toolkit for relevant and quick work with information resources in an easy format. In this case, special attention is paid to users with visual impairments. Modern technologies are capable of not only converting electronic documents to a convenient audio format for a blind user or dotted Braille font, but also provide the blind with a complete computerized workplace with all the possibilities, starting from work in text editors and ending with an access to the Internet or mastering skills on the computer.

When developing electronic libraries for people with special needs, specific methodological approaches are used, tested at creation and formation of traditional libraries. They have a reference search engine and a library and information resource. When forming an informational resource for blind users it is reasonable to accumulate electronic documents in the DAISY format.

3 DAISY Book in the Context of Information Support of the Learning Process

DAISY is an open international information and technology standard for access to multimedia content. The main developer of this standard is the DAISY Consortium, which interacted with a number of professional and civic organizations and formed the conceptual framework of the standard in close cooperation with leading staff of a number of libraries, scientists and user-practitioners. The science and technology

innovation was directed to the main target group of vision-impaired users and users with other physical disabilities. The DAISY book is multimedia content with synchronization of text, audio and graphic information as well as advanced features for flexible navigation in it.

The core of DAISY technology is the effective tools for synchronizing text, graphics and audio based on the W3C recommendations, according to the people's needs that require providing a high-quality special way to information access.

The authors' analysis of the functional capabilities of the technologies that are fixed by the DAISY standard allows us to confirm that it can be used to provide a high quality support of a wide range of requirements inherent in database creation processes that contain multimedia information for the blind as it provides the audio content creation using mechanisms of flexible navigation. Users can listen to such book not only linearly; navigation tools provide an opportunity to make transitions from a section to a section, a subsection, a paragraph, a page. Documents in the DAISY format allow bookmarking of specific places in the text to re-listen to it and put voice tags.

A navigation map is imposed on the audiobook in a certain way and a "reader" can not only listen to the text, but also work with it: make bookmarks, notes, quick access to the necessary information. The DAISY books can be structured or unstructured in general. The decision on the structure of such book is taken when converting it into DAISY format.

The DAISY format books have the MP3 file archiving technique, which can hold up to 90 hours of audio tracks that can be listened to both on special playback devices and on the computer where the appropriate software is installed.

The DAISY format specification uses numerous cross-references among XHTML text files, MP3 audio recordings, SMIL synchronization files, and NCX navigation control. Extensible Hypertext Markup Language (XHTML) is an expanding hypertext markup language based on XML and features similar to HTML.

The DAISY book can consist of audio files, text files and images, or their combinations [10]. All DAISY books use a common set of file types, although some files are optional.

Almost all types of files in the DAISY format are based on XML [11]. The most important types of files that are part of DAISY books are batch, text content, image, audio file, synchronization, navigation management, resource, style presentation and transformations.

4 Technologies for Voice Recognition of Mathematical Expressions in the DAISY Format Books

For the organization of the educational process in the natural sciences, books with a formulaic component are required. For the transfer of mathematical expressions in books created in the DAISY format, the mathematical markup language MathML is used which is an XML element and is designed for use in XHTML documents.

Documents using the MathML language are not directly reproduced by the synthesizer. For the correct reproduction of such documents, various means are used to create different mathematical notations and text descriptions in different languages (except of Ukrainian). Most DAISY format playback players use the notation LAMBDA, LaTeX and Nemeth (Table 1).

Table 1. Encoding mathematical formulas in different notations

Formula encoding (notation)	**Example**
Traditional	$1+\sqrt{\frac{x^2-y^2}{x+y}}(\mathrm{x}-\mathrm{y})=0$
LaTeX	$1+\backslash sqrt\{\ (\ (x**2-y**2)\ /\ (x+y)\ )\ *\ (x-y)\ \}=0$
AMS	$1+(\ (\ (\ x**2-y**2)\ /\ (x+y)\ )\ *\ (x-y)\ )\ //2=0$
Nemeth	$\#1+>?X\wedge 2"-Y\wedge 2"/X+Y\#(X-Y)]\cdot K\ \#0$

Depending on the type of a player, it can voice mathematical formulas, alternative text (verbal description of a formula), work with the structure of a formula, etc. Our developed technology allows us to convert mathematical formulas of different complexity to the form which can further be expressed by the Ukrainian language synthesizer.

In order to automate the process of creation of teaching materials in Ukrainian in the form of DAISY books it was developed an applied programmed system for processing Ukrainian technical texts for people with visual impairments. The basis of the applied system is the modular structure, which makes it possible to implement it as separate functional modules.

The system consists of the components such as drivers of special equipment, basic software and special software. In Fig. 1, in the Special software block, the modules developed during this study are highlighted in the dotted lines:

- a module for processing files of various formats (allows a user to convert the format of an input book according to their needs);
- a module of keyword search in the text (provides search and text marking based on the structural features of a book, as well as mathematical formulas, descriptions of figures, etc.);
- an overlay navigation module on the book (this module is responsible for overlaying the selected navigation scheme on the input document and dividing it into separate parts);
- a module for converting a formula to a text description (provides the transformation of mathematical formulas and special characters into a text description in Ukrainian, in accordance with the rules developed by the transformation);

- a module for content layout and content storage (is responsible for preserving the structural parts of the book text in separate files, as well as giving an opportunity to voice them in Ukrainian).

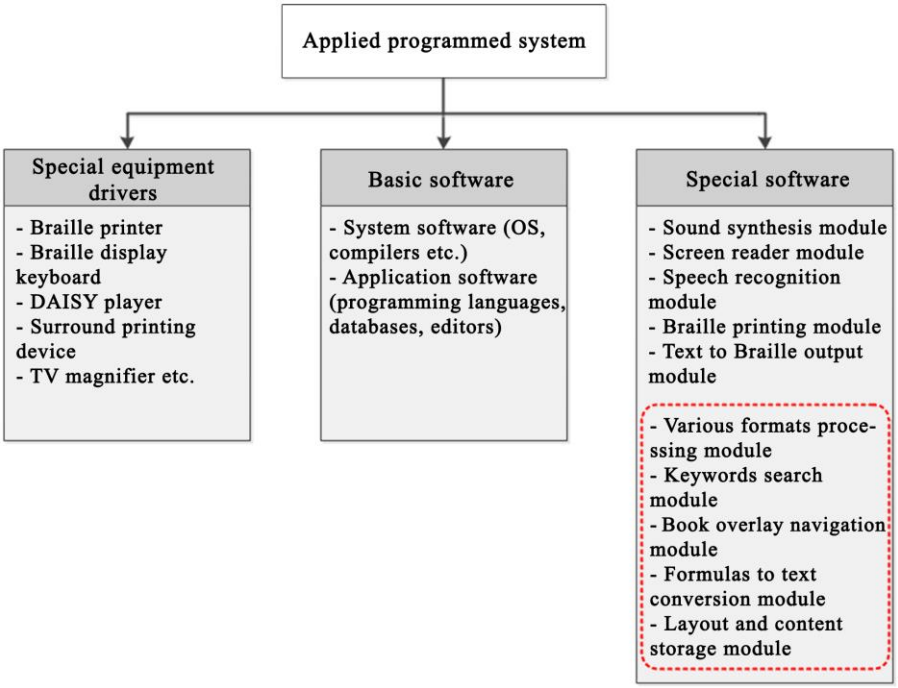

Fig. 1. Structural scheme of the applied system for processing Ukrainian technical texts for people with visual impairments

Each module has a finished functionality, working with an appropriate set of input parameters and output data.

The main function of the applied system for processing Ukrainian technical texts is the processing of information, namely collecting (receiving), processing, storing and displaying. The software interfaces of the system are designed for an inexperienced user, divided into many types of menus with a possibility to dub them with a reading system from the screen or output to the Braille line.

The program module of the applied program system for processing Ukrainian technical texts, which provides the transformation of mathematical formulas into an audio format, is developed by means of the language C # and available at: http://www.mathplay.ho.ua/

In the process of automated recording over information content, there are problems associated with the transformation and presentation of mathematical formulas.

Because of significant differences in constructing and reading mathematical formulas in different languages, it is impossible to adapt English-language systems such as MathPlayer, Dolphin EasyReader, MathSpeak due to differences in the construction of sentences, besides, the indicated software is licensed rather than in open

source. It causes precisely to develop an applied programmatic system for the sounding of Ukrainian technical texts with a formulaic component.

We have not found publications in Ukrainian or Russian that would contain rules for reading mathematical formulas or methods for decomposing mathematical formulas, but there are some publications in English [12, 13]. These publications are basis for the development of rules for decomposition of the mathematical formula. To convert MathML to a text, a transformation model for a syntax tree is used, based on the rules described in these publications.

Taking into account the prevalence of the MathML language, its tree structure and the availability of means for converting formulas in different formats to the MathML language, we consider appropriately it to use for internal formula recording. The MathML language is selected as an intermediate one for the development of means for sounding formulas.

The formula written in the MathML language has a tree structure, which makes it possible to describe the semantics of the mathematical expression unambiguously in the information system. Writing a mathematical formula in the MathML language can be represented as a tree whose vertices are operations and operands. In this case, each node in the tree corresponds to a particular layout, and its branches or descendants are subexpressions. In other words, it is a graphical representation of a mathematical formula that shows how exactly the MathML tags should be inserted in each other for the correct representation of a given mathematical expression on the screen (Fig. 2).

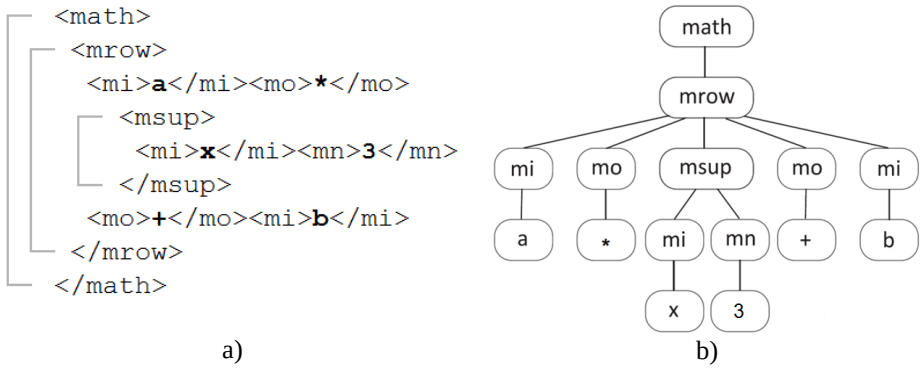

Fig. 2. Formula a * x ^ 3 + b in the language MathML (a), its image in the form of a tree (b)

For the transformation of the mathematical formulas presented in various versions of the MathML (presentation and semantic) record, a special system of rules has been developed for the text in Ukrainian. The system consists of rules for writing mathematical symbols, operators, general and specified expressions.

Rules for specified expressions are necessary in cases when the reading result depends not only on the tree node, but also on the value of its descendant. For example, x^2 should be read the “x square”, and not “xx in power two”. The rules are designed so that the original text could be read with the synthesizer of the Ukrainian language.

The developed rules for the conversion of the mathematical formula are divided into four groups:

1. Character conversion rules. In accordance with these rules, the MathPlay program is designed to convert formula symbols recorded in the MathML language, for example, “x” – “x”, “a” – “a”, “b” – “b”, “c” – “c”, “dt” – “dt”, “\u221E” – “infinity”, etc.

2. Operator conversion rules. With the help of these rules, formulas are transformed, for example, “-“ or “minus” – “minus”, “+” or “plus” – “plus”, “=” or “eq” – “equal”, “times” – “multiply”, “±” – “plus minus”, “(“ – “open a bracket”, “)” – “close a bracket”, “\ u222B” – “integral”, etc.

3. Common expression conversion rules. These rules are used in the following cases:

- raise to the power: “msup” – “*number_1* is raised to the power *number_2*”;
- raise to the power “power” – “*number_1* is raised to the power *number_2*”;
- division: “mfrac” – “*number_1* is divided by *number_2*”;
- extraction of the square root: “msqrt” – “root square from *number_1*”;
- extraction of the root of n-th power: “root” – “root of power *number_1* from *number_2*” etc.

4. Specified expression conversion rules. These rules are used in the following cases:

- “power 2” – “square”;
- “power 3” – “cube”;
- “root 3” – “root cubic from *number_1*”;
- “apply plus” – “*number_1* plus *number_2*” etc.

5 Analysis of the Results of the work of the Applied Program System for Processing Ukrainian Technical Texts

To test the results of the applied programmed system for processing Ukrainian technical texts, five groups of experiments were carried out to convert mathematical formulas presented in various formats into the mathematical markup language MathML, as well as dubbing and perception of the obtained formulas by blind users by ear (Fig. 3).

For experiments on the convertion of formulas into MathML language, a random set of mathematical formulas of various complexity is taken, from simple ones as $\sqrt{a+b}=6$, to complex ones as $f(x)=a_0+\sum_{n=1}^{\infty}(a_n\cos\frac{n\pi x}{L}+b_n\sin\frac{n\pi x}{L})$.

The test base for the first four groups of experiments contained 100 formulas, with 25 formulas per group. Among them, 20 formulas are simple arithmetic expressions, another 20 are trigonometric expressions, 20 ones are integrals and derivatives, 20 are linear algebra formulas and 20 are series, borders, etc.

During the experiments, free software (UkrVox, Ttm, OpenOffice, etc.) and demo versions of commercial products (GrindEQ Math Utilities, InftyReader, MathType, etc.) were used.

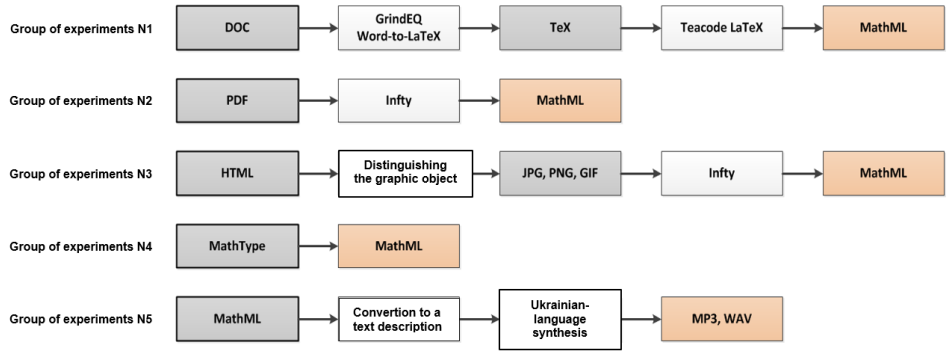

Fig. 3. Conducting experimental research

The group of experiments № 1 (*.DOC → «GrindEQ Math» → TeX → Teacode Latex → MathML).

The first group of experiments was to convert the formula set into the MathML language written as a Microsoft Word document format.

The group of experiments № 2 (*.PDF → Infty → MathML).

The second group of experiments was to convert the formula set into the MathML language written in the Adobe Reader, * .PDF format.

The group of experiments № 3 (*.HTML → selecting graphic objects → JPG, PNG, GIF → Infty → MathML).

The third group of experiments was to convert a formula set into a MathML language written as a * .HTML web page.

The group of experiments № 4 (MathType → MathML).

The fourth group of experiments was to convert a formula set written with MathType into the MathML language and save the copied formula in a text editor with * .MML extension.

According to the results of the conducted experiment, the greatest errors and incorrectness were when the mathematical formulas were recognized by means of the Infty program and converted to the mathematical markup language MathML. Only 21 formulas were correctly recognized from the 50 formulas of different complexity (25 formulas from the experiment group № 2 and 25 formulas from the experiment group № 3). Thus, Infty software, due to the imperfection of the recognition means, provides only 42% of the accuracy of recognition processes of complicated formulas. For example, the formula of medium complexity $\sqrt[3]{(b+c)} = a$ was recognized wrongly, with two errors: 3√ (b + c) = Ω.

In parallel, the processes of converting the formulas to the MathML language by technologies selected for the first and fourth groups of experiments gave the correct result on 100%, and non-significant inaccuracies were recorded for the second and the third groups.

The group of experiments № 5 (dubbing the formulas in Ukrainian transformed into MathML language).

For this group of experiments, 150 different formulas were taken during the research. All formulas are divided into groups: equations (rational, square, linear), inequalities, identical expressions, fractional expressions and functions. Each group included formulas of various complexity.

Experiments were consisted of the correct perception by ear of the mathematical formula dubbing by the developed MathPlay program and recorded it in the notebook during the listening.

Performing experiments on simple formulas (250 formulas), five respondents made two errors during playback, making up 0.8% of the total number of records. According to the calculations of experiments, respondents made 11 mistakes on formulas of average complexity with the same number of formulas, that is, 4.4% of the total number of records. The third part of the experiments over complex formulas showed the following result: 44 errors, or 17.2% of the total number of records.

Consequently, the MathPlay program of dubbing mathematical formulas and symbols has produced a good result. The program correctly reproduces 693 out of 750 records (92.5%) for formulas of various complexity.

According to the participants of the experiments, the main difficulty during the experiments was the understanding of the synthesized voice and high speed of reproduction. In addition, the overall result was influenced by the formula complexity.

6 Interface of a Blind User Interaction with an Electronic Library

One of the most important tasks faced by the developers of the library information and technology service for people with visual impairments is a solution of the issues of the multimedia structured content formation for a convenient interaction of the blind with library services by means of computer.

As the main purpose of developing such system is to maximize the automation of the interaction between a blind reader and an electronic library, the proposed model of the system will provide such interaction by means of an automated workplace through the program interface with special way of input and output information.

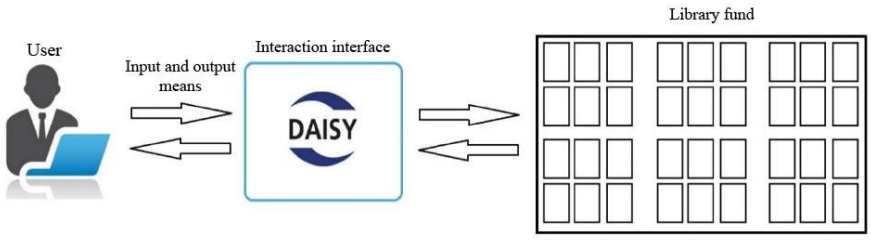

Fig. 4. Interaction process of the blind user and the electronic library

In the Fig. 4 it is shown a block diagram of the interaction process of a blind user with an electronic library. With the help of a specially equipped automated workplace and software interface, the blind user can access to library resources and find a necessary book for reading.

The general scheme of the equipped automated workplace for a blind user consists of basic and special technical means, software, various organizational measures. In addition to working on a computer, a person with visual impairment can receive information from additional technical devices such as a TV, a mobile phone, audio players and magnifying devices, etc. This automated workplace allows synchronizing these devices with a computer for convenient and fast operation.

The system of interaction of a blind user with a computer can be supplemented by additional software and hardware, in accordance with the needs of the blind, in particular, for working with math, graphic objects and musical instruments.

7 Conclusion

The developed software and algorithmic means of sounding mathematical formulas in the Ukrainian language gave an opportunity to voice the technical texts of the Ukrainian language with the help of a language synthesizer, fill DAISY books with technical content and convert mathematical formulas into a text description. An integral part of the soundtrack is a special system of rules, which ensures the correct conversion of the mathematical formulas presented in various versions of the MathML record. The system of rules consists of algorithms for writing mathematical symbols, operators as well as general and specified expressions.

The developed applied programmed system for processing Ukrainian technical texts provides automation of processes for the creation of adapted teaching materials containing mathematical formulas for the needs of a blind user.

Experiments on the correctness of automatic sounding of mathematical formulas carried out during the testing of the applied programmed system for processing Ukrainian technical texts allow us to assert that the developed software product provides a clear dubbing in Ukrainian of 92.5% of the formulas of various complexity. There are no computer technological and methodological analogues of this software product in Ukraine. The presented workings are technologically commensurate with the world's achievements in the field of cutting-edge information technology focused on people with special needs. The applied program system for processing Ukrainian technical texts is used to accompany the educational processes of blind pupils and students.

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