

# Information and Technology Support for the Training of Visually Impaired People

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**Abstract.** There are a lot of scientists who investigate the problem of information accessibility for visually impaired and totally blind people. Considerable contribution to the creation of information technologies for blind people was made in Sweden, Japan, Germany, USA, France, Canada, Denmark, Great Britain and other leading countries. Unlike the leading countries in Ukraine the information accessibility for blind remains problematic and painful. Solving this problem will help blind people to realize themselves in everyday life.

The paper is devoted to solving the actual scientific problem of information availability for people with visual impairments by developing new methods and tools for computer processing and data presentation. The authors presented the developed software system for adapting Ukrainian-language technical texts to people with visual impairments. This system consists of a set of processing and conversion methods for automatic reading mathematical formulas and symbols written in a variety of formats in Ukrainian.

As a result, a program of dubbing mathematical formulas «MathPlay» was developed, which showed overall good results of user understanding at the hearing voiced formulas of different complexity that estimates near 92.5%.

The obtained results can provide the basis for the development of various training programs, practical courses and workouts of blind people working with the computer, as well as for university education.

**Keywords:** Ukrainian technical text processing, visual impairment, syntax tree, sounding, automation equipped working place, DAISY format, markup language MathML.

## **1 Introduction**

Today, there are many pedagogical, programmed and technical means for facilitating the training of people with visual impairments, but further development in this direction is impossible without computer presentation and adaptation of teaching materials to the needs of people with visual impairment.

People with visual impairments are constantly confronted with difficulties in the implementation of their rights. They are deprived of an opportunity to receive information in a natural way, since they are not able to provide themselves properly with the necessary information resources. For example, Braille books or literature in audio formats, not to mention special adaptations for work with computer and Internet access.

Unfortunately, the problem of supporting schools for blind people with didactic materials and tiftotechnic equipment has intensified. The issue of personnel training and support is no less problematic. In special boarding schools there are not enough teachers who have a technique of teaching and educating children with deep visual impairment. Since the system of training such teachers is practically not developed in our country, people who have never worked with blind children come to work in our schools, and this often leads to negative consequences.

The use of modern information technology to provide information to blind people is an urgent problem, the solution of which has found new approaches [1, 2].

Modern computer tools are capable of not only converting digital data into a convenient audio channel or dotted Braille font for the blind, but also provide the blind with a complete computerized workplace with all the opportunities, from work in text editors to access to the Internet or mastering suitable programming languages. Digital Talking Book, covering both audio and text data, are invaluable multimedia information resources for visually impaired people [3].

## **2 DAISY Book as a Tool of the Learning Process**

NIMAS (National Instructional Materials Accessibility Standard) is a technical standard used by book publishers to create XML source files that can be used to develop some specialized formats, for example, for Braille font or audiobooks [4].

Output files are created using the XML markup language to mark up the input content structure; they provide content representation in various forms and styles. For example, XML files and source image files can be used not only for print products, but also for Braille fonts, font size, HTML pages, audio files, DAISY readable books, or with the help of a speech synthesizer, etc.

Adaptation of information resources for people with special needs to the educational needs is most appropriate with the use of the format called DAISY.

The DAISY standard, developed by the American National Institute of Standards and the ANSI / NISO National Standards Organization, sets specifications for digital books for people with complete or partial loss of vision, people with disabilities or other physical disabilities that make reading difficult [5].

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 were 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 [6].

### **3 Methods and Algorithm for Creating DAISY Books that “Speak” in Ukrainian**

As a result of the pilot studies, two methods for creating DAISY “talking” books have been identified and adapted to the Ukrainian language, with the development of the classification of types of books and electronic documents.

The first method consists in reading the Ukrainian-language printed material into a microphone with the subsequent processing of the received audio recording. The second method is to maximize the automation of the process of creating a book, including dubbing of created text files using the synthesizer of the Ukrainian language, as well as the transformation and dubbing of mathematical formulas and graphic objects. As a result, audio records of all parts of the book that are imported into the PRS Pro program are mounted to create the ultimate DAISY book [7].

Then step by step it is described the method of constructing the DAISY book in accordance with the proposed methods.

Step 1: Analysis and classification of input data (the method of classification of documents is used).

Step 2: Defining the book structure and overlaying navigation (it is used the keyword search method and the decision tree method).

Step 3: Finding the most important information in the book using special words (hybrid methods and keyword search method are used).

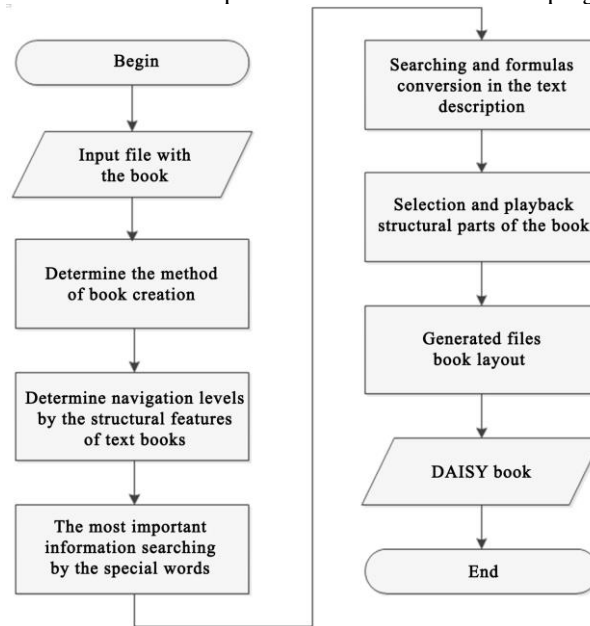
Step 4: Searching for mathematical formulas in the text of the book (using the decision tree method and keyword search method). This process becomes quite hard-working, if the formulas in the graph formats are appearing in the book.

Step 5: Creating a text file describing the formula in the Ukrainian language and its sounding by the language synthesizer (the method of transforming the syntactic tree and the method of synthesis of the sound are used). As a result, we get audio files in MP3 or WAV format.

Step 6: Building the book's current files. At this stage, the software is used to build DAISY books, according to the needs of the developer.

In Fig. 1 it is presented a flow-chart of an audiobook content formation algorithm, in accordance with the developed applied software system. The input file is a text or graphic file, then the program initializes the input file format, determines the optimal method for creating a book and issues the corresponding message to the user (if the format of the input document is different from HTML / XHTML). The next step is to find the most important information in the book by special words or fragments of the text that will be dubbed by the voice of another speaker. At this stage, the hybrid

methods and the keyword search method are used. Then the transformation of the mathematical formulas into the text description and distribution of the book into separate parts according to the navigation parameters are performed. The result is a plurality of output text or audio files for import into the DAISY PRS Pro program.



**Fig. 1.** Flow-chart of the DAISY book creation algorithm

The developed algorithm for creating DAISY books allowed to automate the process of building a “talking” book in Ukrainian. In particular, it has ensured the support of Ukrainian-language technical texts and highlighting the most important information in the book.

#### **4 Technologies for Transformation and Representation of Mathematical Formulas**

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 [8, 9, 10].

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 [11].

Stages of Ukrainian-language technical texts processing:

- formula scanning;
- the formula recognition and transformation into the mathematical markup language MathML (Infty Reader, GrindEQ Math Utilities, Teacode Latex, MathType, TeX etc. [12, 13]);
- text forming for voice (MathPlay);
- sounding the formula in Ukrainian ("Ukrainian voice UkrVox - Igor") [14].

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

In our study, for the internal formulation of formulas, we use the MathML language because of its prevalence, tree structure and the availability of converting formulas, written in different formats to the MathML language. The MathML language is selected as an intermediate one for the development of means for sounding formulas [16-19].

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 "x in power two". The rules are designed so that the original text could be read with the synthesizer of the Ukrainian language [9].

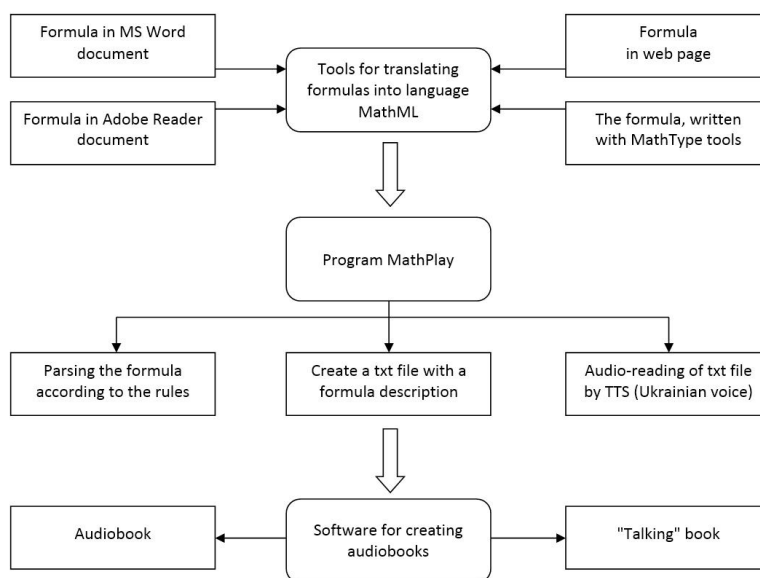
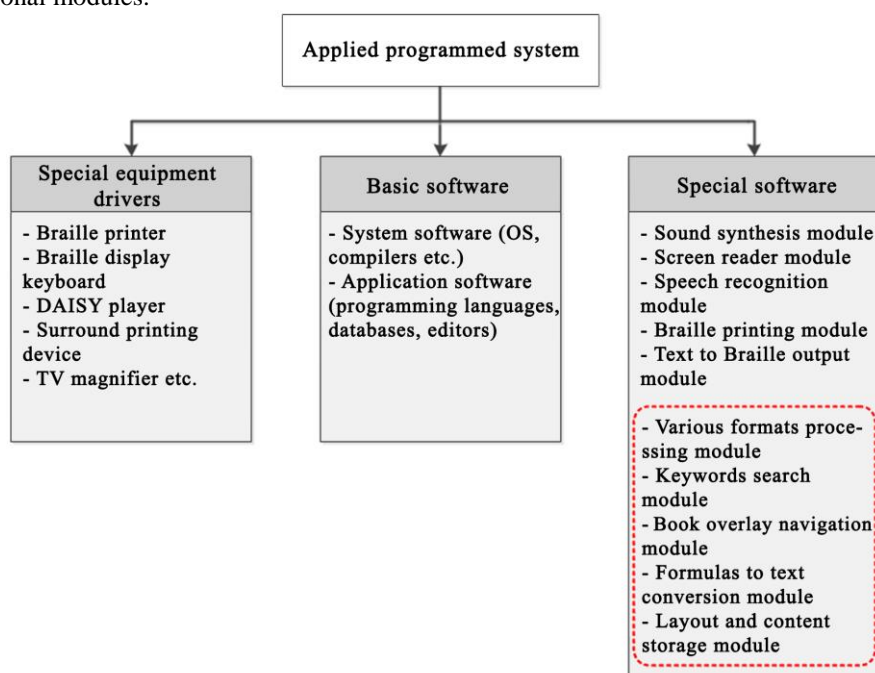


Fig. 2. The process of sounding mathematical formulas in Ukrainian

The tools for converting mathematical formulas recorded in various formats and the MathPlay program are the basis of an applied program system for processing Ukrainian-language technical texts (Fig. 2) and provide a reliable and rapid solution to a group of tasks, such as the transformation of mathematical formulas available in linear text, to the language MathML, the analysis of mathematical formulas in relation to the phonetic and grammatical features of the Ukrainian language, the automatic creation of audio files with Ukrainian-language content, etc.

The developed software and algorithmic means of sounding mathematical formulas in the Ukrainian language gave an opportunity to dub the technical texts of the Ukrainian language with the help of a language synthesizer, fill the DAISY books with technical content and convert the mathematical formulas into a text description.

In order to automate the process of creating educational materials in Ukrainian as a DAISY book, an applied program system for processing Ukrainian-language technical texts for people with visual impairments has been developed. The basis of the applied system is the modular structure, which can be implemented as separate functional modules.



**Fig. 3.** Applied programmed system

The system consists of the following components such as special equipment drivers, base software and special software. In Fig. 3, in the Special software block, the dotted-out modules that were developed during this study are highlighted, namely:

- module for processing files of various formats (it allows a user of the system to convert the format of the input book according to their needs);

- keyword search module in the text (it provides search and markup of the text based on the structural features of the book, as well as mathematical formulas, descriptions of drawings, etc.);
- book navigation overlay module (this module is responsible for applying the selected navigation scheme to the input document and divides it into separate parts);
- module for converting formulas to a textual description (it ensures the transformation of mathematical formulas and special characters into a text description in Ukrainian in accordance with the developed rules of conversion);
- content layout and storage module (it is responsible for preserving the structural parts of the text of the book in separate files, as well as giving an opportunity to dub them in Ukrainian).

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

The main function of the applied system for processing Ukrainian-language technical texts is the processing of information, namely collecting (receiving), processing, storing and displaying. The purpose of the developed system is to maximize the automation of the process of creating “talking” books, the possibility of working with Ukrainian-language technical texts, and the availability of this process for a blind user.

The developed system can be used by a sighted person or a blind user with special computer skills. An ordinary user usually uses the technical support for the system such as a monitor, a keyboard, a mouse, speakers or headphones, a microphone, and external storage media. A blind user uses a keyboard, speakers or headphones, a microphone, a Braille ruler and a Braille printer, external storage media, and so on.

## **5 Experimental Determination of the Correctness of the Developed Software Work**

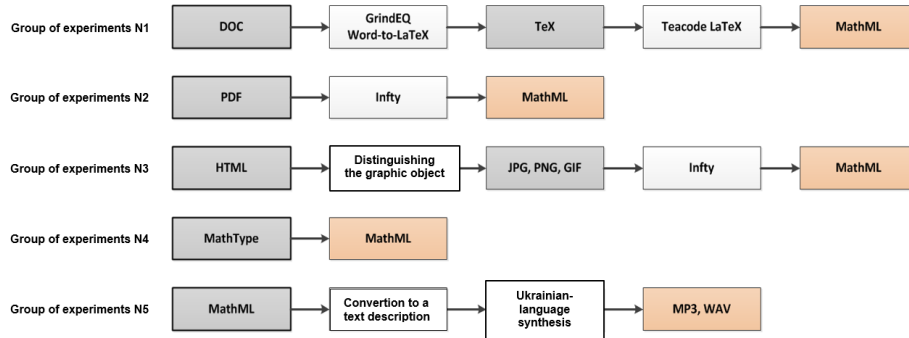
Based on the studied methods of converting formats of mathematical formulas, a knowledge base is developed that provides a convenient representation of the methods of transforming one or another format of a mathematical formula into the MathML language. The knowledge base is a part of the applied program system for processing Ukrainian technical texts for people with visual impairment.

To test the correctness of the developed software work, five groups of experiments were carried out to convert the mathematical formulas presented in various formats into the mathematical markup language MathML, as well as dubbing and perception of the received MathML formulas (Fig. 4).

For experiments on the conversion of formulas into MathML language, a random set of mathematical formulas of various complexity is taken.

The test base for the first four groups of experiments contained 100 formulas, with 25 formulas per each 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.

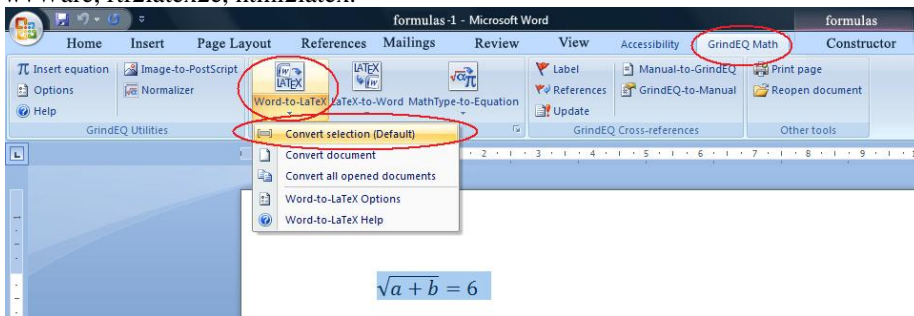


**Fig. 4.** Conducting experimental research

**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 in a Microsoft Word document format and the transformation was performed step by step:

Step 1: The GrindEQ Math Utilities plugin has converted the formulas written in the Microsoft Word document into TeX format (Fig. 5). The GrindEQ Math Utilities plugin contains a set of fully independent components and provides a two-way conversion between Microsoft Word and LaTeX. There are other methods for presenting a Microsoft Word document in TeX / LaTeX, such as Word2TeX, MathType, wvWare, rtf2latex2e, html2latex.



**Fig. 5.** Converting a mathematical formula into TeX format using GrindEQ Math Utilities

Step 2: At this step, the process of converting the formula from the TeX format to the MathML language took place. To do this, the Teacode Latex online service was chosen to provide the TeX formulation and convert it to MathML language, and it also enables to display a formula in a graphic format (\*.PNG) stored on a web server [20]. As a result, the text was obtained in the language MathML, which is copied from the website and stored in a text file with the extension \*.MML (Fig. 6).





**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.

Step 1: To select graphic objects in the browser, open a certain web page with the formula, then save the formula on the computer (clicking the right mouse button on the formula, choose “Save picture as” and save it to your computer). The result is a formula in a graphic format (JPG, PNG or GIF).

Step 2: At this step, the formula is recognized in a graphical format saved from a web page using the Infty tools. To do this, this file is opened in the program Infty - in the “Input File Format” field the input file format \*.PNG is selected, the output format of the XHTML file (MathML) is specified in the “Output File Format” field. The formula is recognized by means of the “Start OCR” button. The result of the recognition is the created XHTML file, which contains the mathematical formula in the MathML language.

**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. Since the default MathType program tools do not allow you to save formulas in the MathML language, this program is configured as follows: in the settings of the program, «Cut and Copy Preferences...» submenu, MathML or TeX is selected - MathML 2.0 (namespace attr) and removed a tick from "Include MathType data in translation" (Fig. 7). This makes it possible to copy the formula translated into the MathML language from the MathType environment. The next step was to save the copied formula in a text editor with \*.MML extension.

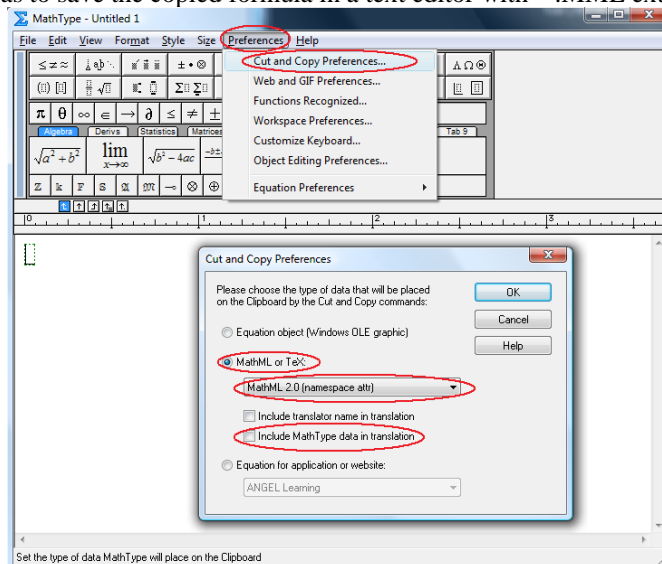


Fig. 7. Configure MathType to convert the formula to MathML

As to the efficiency of converting a formula into the MathML mathematical markup language, it should be noted that the most significant errors were encountered during the recognition of mathematical formulas and their transformation into MathML language using Infy. Only 21 formulas were recognized correctly from the 50 formulas of different complexity (25 formulas from the group of experiments №2 and 25 formulas from the group of experiments №3), which corresponds to 42% accuracy. Due to the inadequacy of the recognition means of this program, 100% accuracy is not ensured when recognizing some complex formulas. For example, the formula of medium complexity  $\sqrt[3]{b+c} = a$  the program Infy recognized wrongly, with such two errors  $3\sqrt{b+c} = \Omega$ . To solve this problem, you need to use an additional tool, it is an editor of InfyEditor and manually edit the formula. The main disadvantage of this method of recognition is the large time expenditures for manual editing of irregularly recognized formulas.

Instead, carrying out the first and fourth groups of experiments gave 100% of the correct result in the case of converting formulas to the language MathML. This is due to the accuracy of the programs and the correctness of the used approaches, as well as the lack of graphical objects that require the use of OCR.

**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 includes formulas of various complexity.

Since a person usually takes  $7 \pm 2$  elements (from 5 to 9 objects) at the same time, which they operate in memory, the formulas have been grouped by complexity. The complexity of a formula was determined by the number of operands, numbers, and mathematical operations.

A formula was considered simple if it met at least one of the following requirements:

- it is less than 5 operands (A, b, x, Z, etc.);
- it is less than 5 mathematical operations (+, =, \*, /, etc.);
- it is less than 5 numbers (5, 16, 32, 12.5, etc.).

For example:  $a + b = x$  ;  $25 - 15 = 10$  ;  $\frac{x}{2} > 16$  ;  $\frac{(a+b)^2}{c} = 4.5$  ;

$$\sqrt{a+b} = 6$$

The complexity of the formula was considered an average if it met at least one of the following requirements:

- from 5 to 6 operands;
- from 5 to 6 mathematical operations;
- from 5 to 6 numbers.

For example:  $\frac{(a-b)*5}{2+2} = x$  ;  $x = \frac{\sqrt{y-4a}}{2a}$  ;  $\log_x y + z = 2ab$  ;

$$\frac{de^x}{dx} = e^x ; \int e^x dx = e^x$$

A complicated formula was considered if it satisfied at least one of the following requirements:

- more than 6 operands;
- more than 6 mathematical operations;
- more than 6 numbers.

For example:  $\frac{1}{(-0)^2} = \frac{1}{+0} = +\infty$  ;  $(a+b)^2 = a^2 + 2ab + c^2$  ;

$$P_1 = P(A) + P(B) - P(AB) ; S = 2\pi RH + 2\pi R^2 ; \cos a = \pm\sqrt{1-\sin^2 a}$$

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 reproduced 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.

For the most part, the Ukrainian language synthesizer "Ukrainian voice of UkrVox - Igor" caused errors during the recording of the stated formulas. Consequently, the development of a high-quality synthesizer of the Ukrainian language will maximize the sound to the natural voice and accordingly increase the percentage of comprehension of the dubbing formula for the first time. The problem of developing a high-quality synthesizer of the Ukrainian language remains relevant and not resolved until the end for a long time.

## 6 Conclusion

Further improvement of the developed technologies can make a significant contribution to solving the problem of people integration with visual impairments into

society, in particular the full education of blind and partially-sighted students in higher education institutions through inclusion in student groups and school clusters.

As a result of the study of the problem of automatic voice recognition of mathematical formulas and symbols, experiments have been carried out which showed that using the MathML tag conversion rule-making system, a qualitative program of voice-assertion of formulas in the Ukrainian language (92.5%) was developed for various complexity formulas.

The obtained results already allow application of the applied program system for the processing Ukrainian-language technical texts in practice for the training of blind users. A knowledge base has been formed with a description of the rules for translating mathematical formulas from a plurality of formats into the mathematical markup language MathML, from which a text file with a description for the synthesizer of the Ukrainian language is generated. As a result, it was possible to develop Ukrainian-language textbooks on technical disciplines in accordance with the DAISY standard. Such books can be used, first of all, to train people with disabilities in mathematical and applied disciplines in both secondary and higher educational establishments.

To further improvement of the means of sounding mathematical formulas in Ukrainian, it should be developed a high-quality synthesizer of the Ukrainian language and improved the methods of data preparation. Hence, it is planned to improve the rules of the formula statement with the addition of terms and clarify the rules of pronouncing large formulas, as well as automate the process of overlaying navigation on the DAISY book pages.

Computer-technological and methodological analogues of developments in Ukraine are not yet available. With regard to the results of foreign research and development, the presentations are technologically proportional to the world-wide achievements in the field of advanced information technology focused on people with special needs.

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