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Proceedings are prepared for publication by PRIP'2014 Program Committee and Belarusian Association for Image Analysis and Recognition. They could be useful for students and researchers working in the following areas: Pattern recognition and Image analysis, Knowledge engineering, Big data, Decision support systems, Fuzzy mathematics and Fuzzy systems, as well as Applications of pattern recognition and image analysis methods.

Papers are published in the form presented by authors who are fully responsible for correctness of the reported results and technical quality.

Сборник включает доклады 12-й Международной конференции "Распознавание образов и обработка информации", которая состоится 28–30 мая 2014 г. в Минске (Беларусь). Сборник подготовлен к выпуску программным комитетом конференции и Белорусской ассоциацией по анализу и распознаванию изображений.

Доклады конференции будут полезны студентам и специалистам, работающим в следующих областях: распознавание образов и анализ изображений, обработка и представление знаний, "большие" данные, системы поддержки принятия решений, основанные на знаниях, нечеткая математика и системы, а также практические приложения методов распознавания образов и анализа изображений.

Статьи печатаются в виде, представленном авторами, которые несут всю ответственность за достоверность приводимых научных результатов.

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THE SYSTEM OF GENERATION OF PHONETIC TRANSCRIPTIONS FOR INPUT ELECTRONIC TEXTS IN BELARUSIAN

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The paper discusses the process of creating a system which automatically produces phonetic transcriptions for input electronic texts in the Belarusian language according to the Cyrillic and Latin alphabetic systems of phonetic notation. The general scheme, the working algorithm, the structure and contents of the specialized knowledge base with correspondences "an allophone – a transcription symbol" are described.

Introduction

The authors' aim is to create a system of the automatic generation of phonetic transcriptions (GT) for electronic texts in the Belarusian language. Fields of use may include various services and applications, such as online text-to-speech synthesis [1], natural-speech interfaces [2] – in order to define the characteristics (i.e. peculiarities of a representation of the sounds of oral language), according to which any Belarusian word can get the correct automatic pronunciation. At present the problem is urgent because there are no specialized algorithms for Belarusian words to automatically receive the Cyrillic or Latin transcriptions.

In order to achieve our goals, we have established the following specific objectives:

– to develop a knowledge base with correspondences "an allophone – a transcription symbol";

– to implement program algorithms which transcribe electronic texts (i.e. generate phonetic notation of each word) according to the Cyrillic and Latin phonetic alphabets;

– on the basis of a GT-system, to create a GT-service accessible via the Internet;

– to work out a generalized scheme of a GT-system for other languages.

For the construction of a knowledge base for the Cyrillic transcription of words, language experts have used scientific materials on the theory of the Belarusian language [3, 4]. The research work [5] has become the basis for a knowledge base of the first Latin transcription, and the resources [6, 7] have been used for a knowledge base of the International Phonetic Alphabet (IPA) which is the other phonetic notation system based primarily on the Latin alphabet.

1. The algorithm for the automatic generation of phonetic transcriptions

In order to build the system which produces phonetic transcriptions, we assume that a user puts an electronic, orthographically correct text in the allophonic representation at the input of the system (fig. 1). Further, the system is supposed to produce transcriptions according to several phonetic alphabets at the output. The allophonic representation of orthographically correct texts can be obtained with the help of an online text-to-speech synthesizer available at www.corpus.by/tts3 [8].

Let us take the following orthographic text with marked stresses, and phonemic words as an example:

Мо=й ро+дны ку+т, я=к ты= мне= мі+лы!
Забы+ць цябе= няЂма+ю сі+лы!

After this text is processed by the text-to-speech synthesizer, its allophonic representation will be as follows:

M004,O113,J'013,/,R032,O022,D001,N004,Y322,/,K001,U032,T000,/,#C3,
J'002,A142,K004,/,T002,Y121,/,M001,N'004,E143,/,M'002,I041,L004,Y310,/,#E2,

Once an electronic text in the allophonic representation is at the input of the GT-system, it becomes possible for a user to select a language of the input text, and a desirable phonetic

transcription. For now the system can convert Belarusian electronic texts to their phonetic transcription using three types of phonetic notation systems: transcription by Cyrillic characters (let us sign it with Tr_1), transcription by Latin characters on the basis of [5] (Tr_2), and transcription by Latin characters according to the international standardized format, namely IPA (Tr_3).

The results of using the algorithm are given to a user in the form of a transcribed text according to the desirable phonetic alphabet. At the same time linguistic experts and software engineers receive all the input, output, and analytic data (a size of a text, an IP-address, time, etc.) for efficient correction of errors in the process of producing transcriptions.

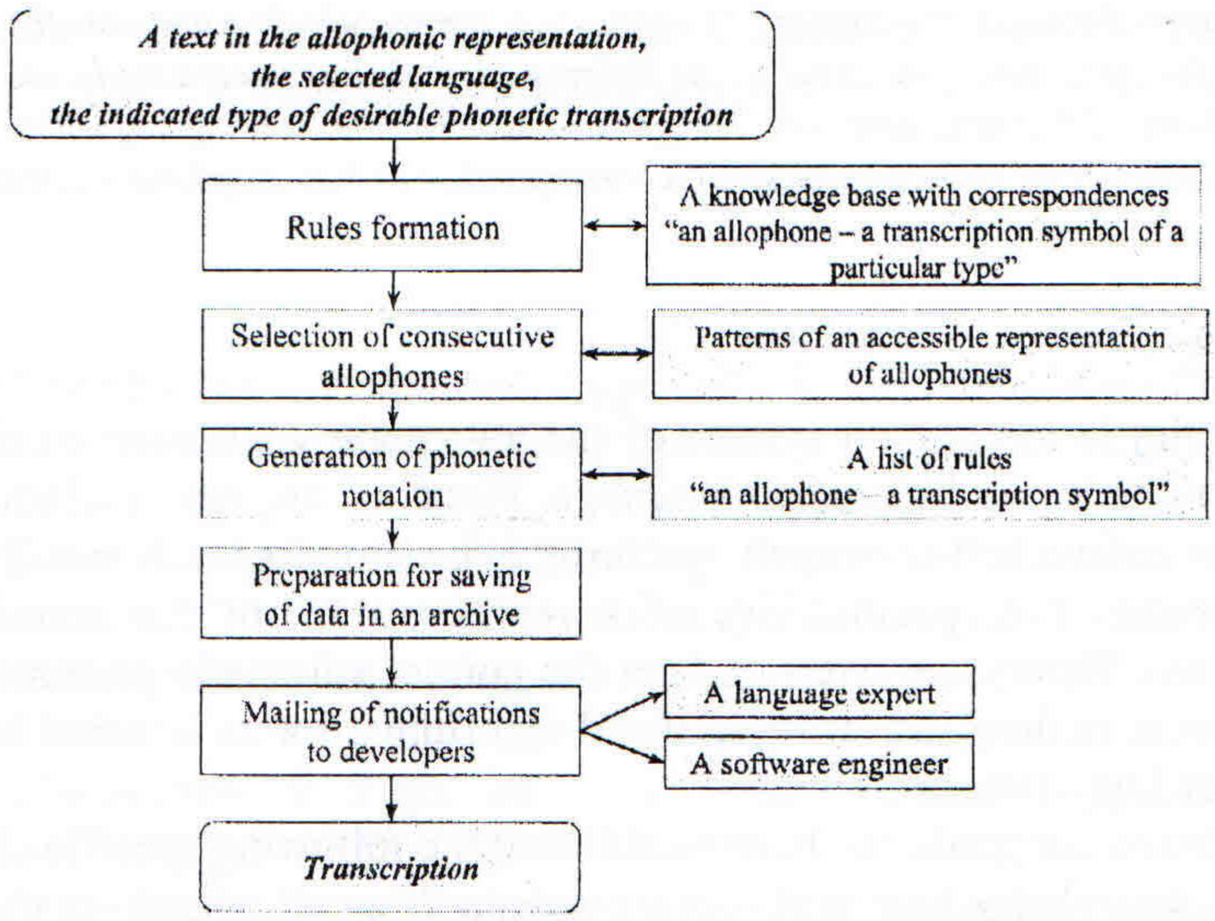


Fig. 1. A generalized scheme of the algorithm for the automatic generation of phonetic transcriptions

Let us consider in detail the algorithm of work of the GT-system.

The algorithm requires the following data at the input: an electronic text T in the allophonic representation, a language L, and a desirable type of a phonetic alphabet according to which the transcription process will be performed Tr_t. Further the algorithm fulfills the following steps:

Step 1. *Formation of replacement rules.* At first the algorithm accesses a knowledge base of the language L chosen by a user. The knowledge base contains correspondences "an allophone – a transcription symbol". Then a number of replacement rules $R = <R_1,...,R_n>$ are formed, where $R_i = <a_i, tr_{i1}, tr_{i2}, tr_{i3}>$; a_i is an allophone code; tr_{i1}, tr_{i2}, tr_{i3} denote characters of three types of transcriptions of an allophone a_i; $I = 1...n$; n is the quantity of rules.

Step 2. *Allophonic representation of a text.* In the text T, allophones are selected according to the pattern Pt of their accessible view. The pattern Pt can be formalized by means of the language of regular expressions in the following way: $Pt = [A\text{-}Z]\{1,3\}[']\{0,1\}[\backslash d]\{3\}$, where $[A\text{-}Z]\{1,3\}$ is one, two or three capital letters of the Latin alphabet, $[']\{0,1\}$ means a possible apostrophe sign, $[\backslash d]\{3\}$ signify three digits $(0,...,9)$. The fulfillment of this step is necessary because theoretically a user can place a text in any representation at the input of the system. In this case conversion of such a text requires its preliminary normalization, i.e. extraction of a text in the allophonic representation T_a out of the input text T.

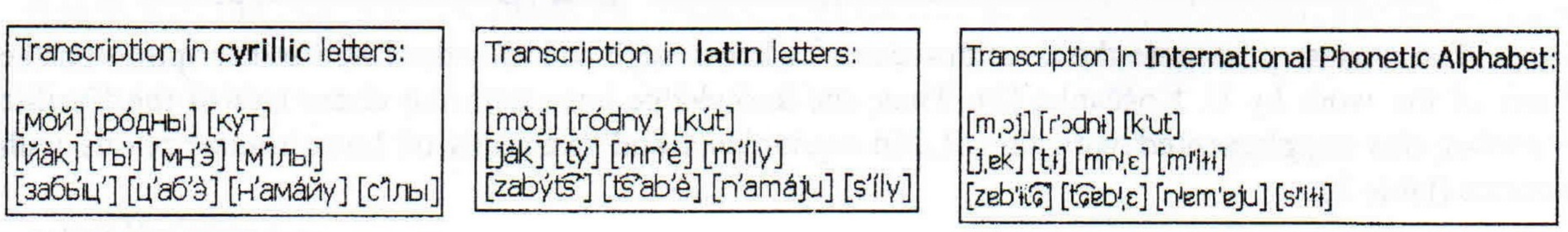
Step 3. *Generation of transcriptions, namely phonetic notation.* For each allophone a_i which is sequentially taken from the text T_a, a transcription symbol of one or another type tr_{ij} is generated according to rules R which have been created earlier. The consecutive processing of the whole text T_a results in the final transcription Tr of the selected type Tr_t.

Step 4. *Preparation for data saving.* During the automated phonetic notation, all the information on the process is gathered. This information includes various input (an allophonic text T, a language L, a desirable type of transcription Tr_t), output (a transcribed text Tr), and analytic (a size of a text, an IP-address, request time, etc.) data. Afterwards the data collection is used by developers to efficiently correct errors (if they occur) in the process of transcriptions generation. It should be noted, that if one

or another element of the knowledge base "an allophone – a transcription symbol" is missing, the system gathers this information as well.

Step 5. *Mailing of notifications to developers.* After the fulfillment of step 4 the above-mentioned data are attached to an e-mail letter which is sent to developers – a language expert and a software engineer – for determining the type of a problematic situation (linguistic mistakes, errors of algorithms and program codes), and the best way to solve it.

Step 6. *The end of work of the algorithm.* As a result, after the algorithm is accomplished a user receives a transcribed text. Fig. 2 illustrates some examples of phonetically transcribed text lines.



a) b) c)

Fig. 2. The example of the resulting text which has been transcribed according to the Cyrillic alphabet (a), simplified Latin alphabet (b), and IPA (c)

High-quality work of the algorithm of the GT-system requires the existence of rules *R* which can give the corresponding transcriptions tr_{i1},tr_{i2},tr_{i3} to any input allophone. A linguistic expert was instructed to develop records for a knowledge base which would correspond to any possible input set of allophones of Belarusian texts according to [9]. In addition each record of a knowledge base is required to be actualized (i.e. filled with all types of transcriptions). Let us consider the process of developing a knowledge base for the system of transcriptions generation.

2. The development of a knowledge base for the system of transcriptions generation

For automatic phonetic notation, it is necessary to create tables of correspondences of allophones with transcription symbols. Initially, our work was carried out in the direction of creating a generator of the Cyrillic transcription. That is why at first we started to create a list of "allophone – transcription" correspondences for this type of transcription. For this purpose, an expert selected 720 words in order to cover all possible occurrences of allophones by the text-to-speech synthesizer. Further a specialist in phonetics used these words for the creation of a knowledge base for the Cyrillic transcription and its analysis (table 1). It was stated that in order to correctly and unambiguously transcribe a word (in its allophonic representation), the first three characters of each allophone are enough, instead of a maximum of five characters that might be given out by a phonetic processor of a text-to-speech synthesizer.

Table 1

Transformation of words into the Cyrillic transcription (an excerpt)

Word	Cyrillic transcription	Allophonic sequence
зверабо+й.	з'в'эрабо́й.	Z'0,V'0,E2,R0,A2,B0,O0,J'0,
бамбё+жка.	бамб'о́шка.	B0,A2,M0,B'0,O0,SH0,K0,A2,
адду+шына.	ад:у́шына.	A2,D1,U0,SH0,Y3,N0,A2,

In the Cyrillic transcription, the following diacritics are used: the acute accent (´) and the grave accent (`) – the main and side verbal accents which are put directly above a stressed vowel; the colon (:) – a reduplication sign; and the apostrophe (') – a palatalization sign.

After that, an expert correlated all existing allophones with the Cyrillic transcription characters for further automation of the process of transforming sequences of allophones into transcribed records according to the Cyrillic phonetic alphabet (table 2).

Table 2

Allophones with their corresponding symbols of the Cyrillic transcription, and examples of words containing them (an excerpt)

Allophone	Cyrillic transcription symbol	Word example
A0	á	катала+жка
A1	à	дзя=ржбюджэ+це
A2	a	ураджэ+нка.
A3	a	навако+лле.

The next step became the development of a knowledge base for the Latin transcription on the basis of the work by U. Koščanka [5]. Thus, the knowledge base with the characters of the Cyrillic alphabet was supplemented with their Latin equivalents and examples of Latin transcriptions with accents (table 3).

Table 3

Transformation of words into the Latin transcription (according to the [5]) (an excerpt)

Allophone	Word example (1)	Latin transcription symbol [5]	Word example (2)
E0	канстэ+бль.	é	kanstébl’
E1	тэ=леперада+ча.	è	tèl’ep’eradátṣa
E2	тэа+тр.	e	teátr

However, after we analyzed the results of the created table, it became obvious that the Latin transcription we had received could not be called international because it did not correspond to the International Phonetic Alphabet (IPA) [6, 7]. In order to achieve our goal we started to deeply analyze the IPA, and to search for equivalents of Belarusian sounds.

There are twenty eight different characters for vowel sounds in the IPA. These characters are systematized in a certain articulation classification [6, 7]. In order to identify relevant sounds, we compared this classification to the corresponding classification of vowels of the Belarusian language [3]. As a result, six necessary sounds were added. Next we found equivalents for all consonants.

Then two more columns were added to the described knowledge base. One of them illustrates sounds in the representation according to the international format, while the second one contains examples of words converted into the international transcription (table 4). At the same time stresses in word examples were put not on vowels, but on syllables, as it was in the Cyrillic, and previously described Latin transcriptions. Putting such an accent complies with the international format.

Table 4

Transformation of words into the Latin transcription (according to the IPA) (an excerpt)

Allophone	Word example (1)	Latin transcription symbol (IPA)	Word example (2)
C'0	пацо+кваць.	t͡ɕ	pɐˈt͡sɔkvɐt͡ɕ
CH0	трагі+чны.	t͡ʃ	trɐˈɣʲit͡ʃnɨ

Thus, we have developed the knowledge base for the system of transcription generation for the Belarusian language. The knowledge base makes possible to put a symbol of one of three desirable phonetic alphabets in correspondence with any allophone which can be generated by the system of text-to-speech synthesis.

Conclusion

This paper says about the beginning of work on the development of a system for the producing of different transcriptions for any input electronic texts in the allophonic representation in the Belarusian language. Its experimental prototype has been implemented as a free service, constantly available on the Internet at http://www.corpus.by/convertAllophToCyrPhonemes/ together with the resource www.corpus.by [4, 10]. With its help, one can automatically receive real-time transcription of any Belarusian allophonic text pieces according to three phonetic alphabets.

The service quickly transforms a text according to the Cyrillic or Latin transcription, understandable to anyone since school. Converting into the international IPA transcription opens up the possibility for foreigners to facilitate understanding of the phonetics basics of a Belarusian written text. In addition to the direct use of the service as a tool for learning the Belarusian language, it becomes also possible to quickly and automatically create specialized Belarusian phonetic dictionaries which can significantly help phoneticians. Besides, using this service together with the text-to-speech synthesizer allows a user to control and correct the work of the synthesizer with the help of notifications sent by e-mail. Further improvement of the system will lie in the integration of the system with the output of the allophonic processor of the text-to-speech synthesizer, and identification of the errors found. It is also planned to modify the algorithm of placing the correct accents (on a stressed syllable, not on a stressed vowel) for the IPA transcription.

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