A Prototype of the Computer System for Speech Intonation Training

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***Abstract*—In this paper we describe the importance of intonation in human comprehension of speech. We lay out fundamental principles of intonational theory of speech that is based on the concept of universal melodic portraits. In this paper we describe the main algorithms of analysis and interpretation of intonation in an utterance that underlie the developed computer-based system for teaching of speech intonation. We further show the system's output and discuss its usefulness in teaching foreign language intonation.**

***Keywords*—Intonation of speech, speech analysis and synthesis, melodic portrait, intonation analysis and interpretation, computer system for teaching, intonation training.**

I. Introduction

Intonation plays significant role during speech comprehension. Without intonation, it's impossible to understand the expressions and thoughts that go with words.

Speech intonation shows a communicative intention of an utterance, its logical meaning, a prominence of the most significant theme in relation to general themes (actual division of a sentence), a distinction between semantically associated segments of speech, and an integration of speech elements within these segments. We can therefore think of intonation as referring to the way we use the pitch of our voice to express particular meanings and attitudes. The exact relation between intonational patterns and informational structure (as part of semantics) is still to be investigated.

A common linguistic idea is that foreign accent appears more evident in intonation, and therefore, prosodic aspects of speech should be explicitly taught to students who wish to communicate intelligibly in a foreign language. Foreign accent arises due to contact between two different language systems, namely, at bilingualism, because of language interference. Intonation is the most important aspect of speech that provides both linguistic and sociocultural information. Considering that functions of intonation in speech are various, and that deviations in this area can lead to significant semantic differences, incorrect intonation can make a wrong impression during the speech of a non-native language speaker [1].

In this view, is it very important to emphasize intonational aspects of speech while teaching foreign language. In [2] an automatic intonation assessment system for computer aided language learning is described. The similarity between reference and test intonation templates is evaluated on a frame-by-frame basis by using the DTW alignment by estimation of the correlation between both F0 curves. Previously [3 – 5], we've published several scientific results in the area of speech intonation analysis and synthesis which can serve as a foundation for the creation of innovative intelligent systems of automatic intonation assessment for computer aided language learning.

II. General information about speech intonation

In phonetics and physiology of speech, a phrase is considered to be a comparatively independent unit in speech intonation [6]. Phrase independence manifests itself in articulatory integrity, semantic and syntactical association of linguistic units, and in presence of objective traits that allow singling it out from a speech stream. Any punctuation mark can set a boundary of intonation phrase in a written text. However, quite often the number of phrases can be greater than the number of punctuation marks. Generally, a phrase is a combination of one to five words, with a three-word phrase being the most common. A particular place of a phrase boundary is determined by the optimal satisfaction of the semantico-syntactic, phonetic and physiological requirements. The first of the named requirements prescribes a union inside a phrase between semantically connected words that cannot be split into two phrases. The second requirement denotes the tendency of language phonetic systems for definite rhythmical construction, for example, a group of two to three words combined in one phrase. Finally, the third requirement prescribes the formation of a phrase with the number of words that could be physically pronounced during the time required for one act of exhaling.

After definition of a phrase, the next step in intonational speech analysis is determination of a phrase intonation type. The main intonation phrase types include: completed and uncompleted phrases, special and common questions, exclamation phrases, and some others types. The number of intonation subtypes of the main phrase intonation types could reach several dozens. The task of definition of an intonation subtype is achieved by the analysis of two factors: the position of a phrase in a text and by its semantic value. The first factor, a position in a text, is determined by the analysis of a phrase position in relation to the nearest punctuation marks. For example, its position at the beginning or the end of a text, its position before or after punctuation marks, and the type of punctuation mark in a sentence. The second factor, a semantic value of a phrase, is determined based on the meaning of a phrase and on its logically emphasized intonational center. In particular, it needs to be determined whether a phrase expresses intentions, explanations, follow up questions etc. The final decision on an intonation type and subtype of a phrase is made after considering both factors.

Speech intonation is physically realized by the set of acoustic means, named the prosodical parameters:

- melodics - the movement of the frequency of the main tone (F0);
- energetics - the current change of the force (amplitude) of the sound (A);
- rhythmics - the current change of the duration of the sounds and pauses (T).

Since melodics of speech is the most informative among these parameters, the main attention in this article is given to the melodics.

III. Block diagram of the suggested computer system for speech intonation training

Figure 1 contains a block diagram illustrating sequence of algorithms for analysis of speech intonation within the developed computer training system. The main goal of the system is to provide a student with a compact and easily interpretable image for the results of analysis of melodic and energy contours of phrases with different intonation. The system would also provide a visual, auditory and numerical evaluation of the quality of learning of a foreign speech intonation by a student.

Block 1 contains the database of phrase samples with different intonation patterns which is compiled from multimedia textbooks (see, for example, [7] for Russian language, or [8] - for English). Every sample phrase has preliminary placed prosodic marks that include phrase boundaries and placement of its nucleus.

Based on a given goal of intonation learning, a student chooses the needed sample phrase, hears it and pronounces it. The pronounced phrase is recorded on the buffer (block 2).

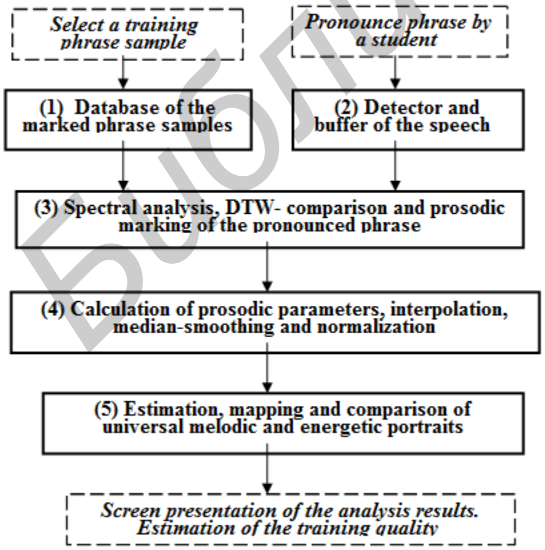

Select a training phrase sample
Pronounce phrase by a student
(1) Database of the marked phrase samples
(2) Detector and buffer of the speech
(3) Spectral analysis, DTW- comparison and prosodic marking of the pronounced phrase
(4) Calculation of prosodic parameters, interpolation, median-smoothing and normalization
(5) Estimation, mapping and comparison of universal melodic and energetic portraits
Screen presentation of the analysis results. Estimation of the training quality

Figure 1. The block diagram of the computer training system of foreign speech intonation

In block 3, the signals from both sample and pronounced phrases are analyzed by calculating Mel-frequency cepstral coefficients (MFCCs) and then compared using the modified method of DTW – continuous dynamic time warping (CDTW) [9]. This is accompanied by determination the beginning and the end of the pronounced phrase, a transfer of prosodic marks (phrase boundaries and placement of its nucleus) and labeling of a pronounced phrase.

In block 4, prosodic phrase parameters of both sample and pronounced speech signals, such as F0 – frequency of the basic tone (pitch), and A0 – energy of the signal, are calculated. These parameters are further interpolated on the non-vocal areas of speech signal, and then they are median-smoothed and normalized on their minimum and maximum of phrase values.

In order to calculate the proper value of training quality, in block 5, an estimation and comparison of universal melodic and energetic portraits are produced.

Figure 4 presents illustration of system's output for the interrogative phrase: "Did Sasha eat the porridge?" The image shows successive processing F0 (t) and A0 (t) and a comparison of the sample phrase and the student-spoken phrase speech signals.

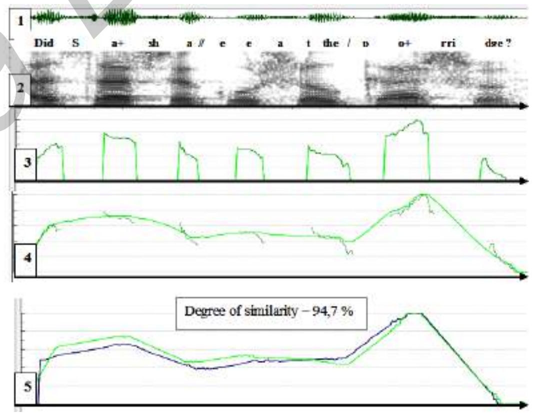


Figure 2. The illustration of speech signals processing: 1- oscillogram, 2 – spectrum, 3 – F0(t) (original), 4 – F0(t) (after interpolation and median smoothing), 5 – comparison of two melodic curves F0 (t) - sample and spoken phrases

IV. Software realization of the computer system prototype

Software realization of the prototype is written on C++ programming code by using Qt framework. It can be compiled under Windows platform (from xp to 10 versions), also under Linux platform.

Application used following libraries:

- OpenAL - used for multimedia interaction (audio input/output). OpenAL is a cross-platform audio application programming interface (API). It is designed for efficient rendering of multichannel three-dimensional positional audio;
- MathGL - used for draw graphics. MathGL is a library for making high-quality scientific graphics under Linux and Windows;

- GNU Scientific Library (GSL) - used for data calculation and processing. GSL is a numerical library for C and C++ programmers. It is free software under the GNU General Public License;
- SPTK - used for audio data analyzing. SPTK is a suite of speech signal processing tools for UNIX environments, e.g., LPC analysis, PARCOR analysis, LSP analysis, PARCOR synthesis filter, LSP synthesis filter, vector quantization techniques, and other extended versions of them.

Application core divided into several modules that implement standalone functions. Such modules can implement audio signal recording, voice detection, DP processing and so on. As this modules a independent from each other, we can easily build different applications by replacing this modules for other one or integrate them in external systems.

For build main user interface used built-in web engine. User interface built on html5, css3 and js (ReactJs js framework). ”Developer mode” user interface build on standard Qt forms.

Main user interface is independent from application core and can be modified or even replaced by other one. Use html/css/js standard allow easy change application front-end for different purposes. For interaction with application core exists a number of special links formats that processed by application core. Such links can open different applications dialogs (like settings, developer mode and so on), process input audio signals and play audio files.

So we can easy build different training systems by replacing front-end and training data files.

The starting page of the User Interface is shown in figure 3. From this page, also possible to pass in “Developer mode”.

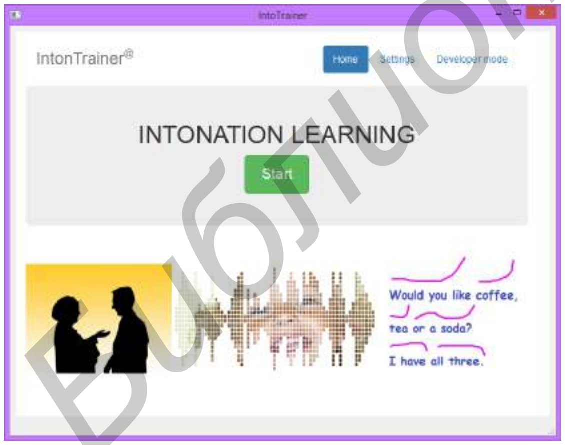


Figure 3. Starting page of the User Interface

After clicking the ”Start” button, a new window opens (see. Figure 4) in which a list of training phrases appears. When selecting one or another test phrase, there is an additional window where you can choose from 3 options: “Show pitch”, “Show energy” or “Show spectrum”.

When selecting the “Developer mode” one can see the full list of test phrases (see Figure 5). In this mode one can choose additional options clicking the buttons: “Evaluation”, “Record”, “Play”, “Remove”, “Rename” and “Settings”.

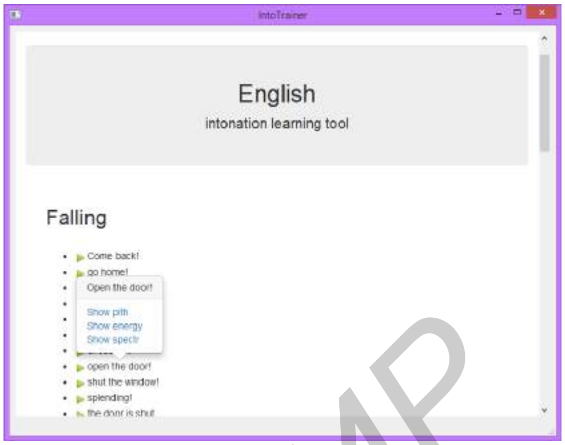
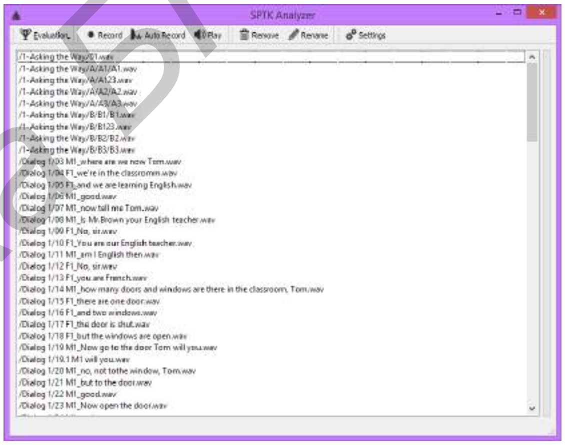


Figure 4. The page of the test phrases selection



/1-Asking the Way/S1.wav
/1-Asking the Way/A/A1/A1.wav
/1-Asking the Way/A/A123.wav
/1-Asking the Way/A/A2/A2.wav
/1-Asking the Way/A/A3/A3.wav
/1-Asking the Way/B/B1/B1.wav
/1-Asking the Way/B/B123.wav
/1-Asking the Way/B/B2/B2.wav
/1-Asking the Way/B/B3/B3.wav
/Dialog 1/03 M1_where are we now Tom.wav
/Dialog 1/04 F1_we're in the classromm.wav
/Dialog 1/05 F1_and we are learning English.wav
/Dialog 1/06 M1_good.wav
/Dialog 1/07 M1_now tell me Tom.wav
/Dialog 1/08 M1_Is Mr.Brown your English teacher.wav
/Dialog 1/09 F1_No, sir.wav
/Dialog 1/10 F1_You are our English teacher.wav
/Dialog 1/11 M1_am I English then.wav
/Dialog 1/12 F1_No, sir.wav
/Dialog 1/13 F1_you are French.wav
/Dialog 1/14 M1_how many doors and windows are there in the classroom, Tom.wav
/Dialog 1/15 F1_there are one door.wav
/Dialog 1/16 F1_and two windows.wav
/Dialog 1/17 F1_the door is shut.wav
/Dialog 1/18 F1_but the windows are open.wav
/Dialog 1/19 M1_Now go to the door Tom will you.wav
/Dialog 1/19.1 M1 will you.wav
/Dialog 1/20 M1_no, not tothe window, Tom.wav
/Dialog 1/21 M1_but to the door.wav
/Dialog 1/22 M1_good.wav
/Dialog 1/23 M1_Now open the door.wav

Figure 5. The “Developer mode” window

When selecting the “Evaluation” in the “Developer mode” window one can see the acoustic parameters of the test phrase (Figure 6), or the smoothed F0-parameter of the test phrase (Figure 7), or the F0-correlation between the test phrase and the same phrase pronounced by student (Figure 8).

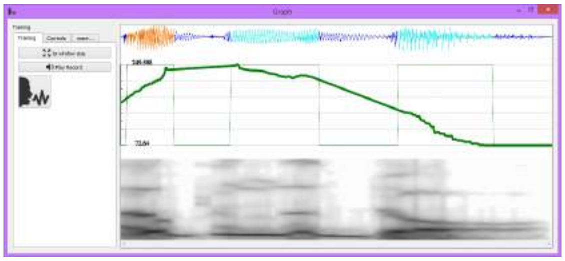


Figure 6. Showing of the acoustic parameters of the test phrase

When selecting the “Settings” in the “Developer mode” window one can change some speech analyzer parameters, such as: frame size, frame shift, type of frame windows, LPC order and others (see Figure 9).

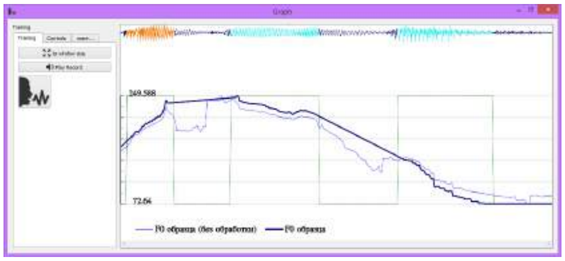


Figure 7. Showing of the smoothed F0-parameter of the test phrase

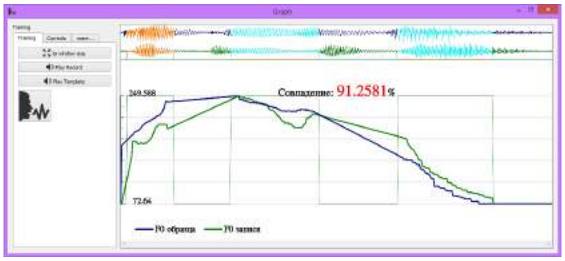
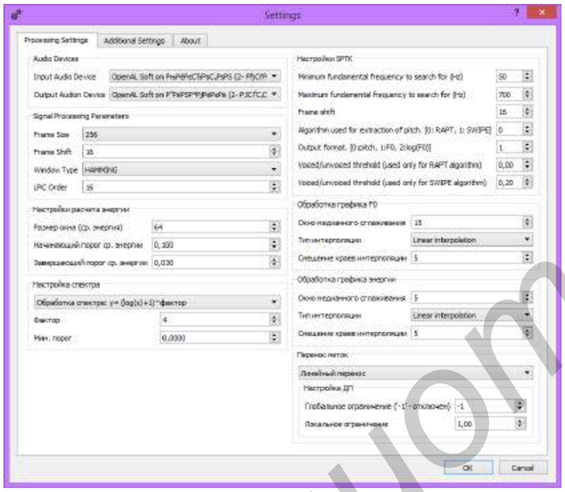


Figure 8. Showing of the F0-correlation between the test phrase and the same phrase pronounced by student


Settings

Processing Settings | Additional Settings | About

Audio Devices

Input Audio Device: OpenAL Soft on РњРёРєСЂРѕС„РѕРЅ (2- РЎСЃР

Output Audion Device: OpenAL Soft on Р"РёРЅР°РјРёРєРё (2- РЈСЃС‚С

Signal Processing Parameters

Frame Size: 256

Frame Shift: 16

Window Type: HAMMING

LPC Order: 16

Настройки расчета энергии

Размер окна (ср. энергия): 64

Начинающий порог ср. энергии: 0,100

Завершающий порог ср. энергии: 0,030

Настройка спектра

Обработка спектра: y= (log(x)+1)^фактор

Фактор: 4

Мин. порог: 0,0000

Настройки SPTK

Minimum fundamental frequency to search for (Hz): 50

Maximum fundamental frequency to search for (Hz): 700

Frame shift: 16

Algorithm used for extraction of pitch. [0: RAPT, 1: SWIPE]: 0

Output format. [0:pitch, 1:F0, 2:log(F0)]: 1

Voiced/unvoiced threhold (used only for RAPT algorithm): 0,00

Voiced/unvoiced threhold (used only for SWIPE algorithm): 0,20

Обработка графика F0

Окно медианного сглаживания: 15

Тип интерполяции: Linear interpolation

Смещение краев интерполяции: 5

Обработка графика энергии

Окно медианного сглаживания: 5

Тип интерполяции: Linear interpolation

Смещение краев интерполяции: 5

Перенос меток

Линейный перенос

Настройка ДП

Глобальное ограничение ('-1' - отключен): -1

Локальное ограничение: 1,00

OK | Cancel

Figure 9. The "Settings" mode window

V. Conclusion

We believe, that there is a great potential in both domestic and international markets for a new and innovative product such as the proposed computer system for intonation training integrated into a foreign language educational courseware. To our knowledge, there is no satisfactory software available for such teaching system and, therefore, such system appears to be of great relevance. For example, there are considerable intonational differences between Russian and English languages. American English native speakers made the following interesting observation: "Ask an average American what they are thinking about the Russian accent, and the answer will be as follows: "Russians don't sound very friendly. I feel like they don't like me at all. I am not sure whether it comes from their language or from their culture?" One of the reasons why native Russian speakers sound unfriendly in English is the so called "flat" tone. Native Russian speakers often do not use language-specific phonological representation of intonation during their conversation in English. Moreover, native Russian speakers tend to avoid using rising and falling intonations in English and, as a result, Americans may find their speech unfriendly and unpleasant.

Application of an intonation mapping analyzer as a part of a speech recognition system is expected to increase reliability of recognition through the prominence of accented words and intonational segmentation of a speech flow. Intonation analysis will also be helpful for subsystems of identification of individual and emotional factors of speaker's speech. The use of intonation system in speech synthesis systems will give an opportunity to improve intonational prominence of synthesized speech so that it will positively affect listener's comprehension.

References

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ПРОТОТИП КОМПЬЮТЕРНОЙ СИСТЕМЫ ОБУЧЕНИЯ РЕЧЕВОЙ ИНТОНАЦИИ

Лобанов Б.М., Житко В.А.

В статье обосновывается важность интонации для восприятия и понимания речи человеком. Описаны фундаментальные принципы интонационной теории речи, которая основывается на концепции универсальных мелодических портретов. В статье описываются основные алгоритмы анализа и интерпретации фразовой интонации, которые лежат в основе разработанной компьютерной системы, предназначенной для обучения речевой интонации. Показаны выходные характеристики системы и обсуждается её полезность в обучении интонации иностранного языка.