# The Project of Lingua Franca Communication Simulator Development

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**Abstract.** This study is carried out for Department of Linguistics and Intercultural Communication, FEFU. The goal is to create a computer simulator that allows reproducing the process of production and perception of foreign-accented speech in the context of intermediary language communication. The work of the simulator is based on the principle of evolutionary modeling with variable model parameters and different sets of input data. This will provide researchers with the instrument to reproduce various communicative situations occurring among non-native speakers of English in Asia Pacific Region.

## 1 Introduction

Sociolinguistic aspects of the problems related to interlingual and intercultural interaction, along with the practical need to increase the efficiency of English-mediated communication in the actively developing multiethnic Asia-Pacific region (APR), emphasize the relevance of this study. Formed as a result of the diverse linguistic and cultural contacts between East and West, the APR's polilingual and multicultural "space" demonstrates unique structural and functional features. These are determined by two types of forces — "centrifugal" and "centripetal", which act simultaneously, due to the objective linguo-cultural heterogeneity of this "space" and its residents' pursuit of comprehensive integration through common intermediary language. Since the Russian Far East is intended to offer an integrative platform for the globalization processes in the APR (as set by RF Government Strategy for the development of the Far Eastern Region and Transbaikalie until 2025), a comprehensive study that aims to provide a toolkit on how to conduct an effective dialogue in English as a lingua franca in such a specific region of the world, is vastly significant.

It is the pragmatic steps needed for global intercultural interaction in the modern world that demand new approaches to examining the problems of language and culture contacts, taking into account the data obtained in recent comparative typological, neuro-, psycho- and sociolinguistic, linguistic and culturological, linguodidactic and other studies. At the same time, the description of the linguistic and cultural specifics of the APR from the standpoint of contact variantology of the English language requires special attention. This is because the linguistic situation in


In: P. Sosnin, V. Maklaev, E. Sosnina (eds.): Proceedings of the IS-2019 Conference, Ulyanovsk, Russia, 24-27 September 2019, published at http://ceur-ws.org

the APR, and its East Asian part in particular, is different from the European one, as it is characterized not only by ethnocultural distantness, but also by genetic and typological heterogeneity, and, consequently, by mutual incomprehensibility of the region's numerous autochthonous languages and dialects. Additionally, while the majority of European languages received a detailed description of genetic, typological and areal features in the linguistic literature, the same is not true about East Asian languages. For instance, even the kinship ties of the neighboring Korean and Japanese languages, both having rather high communicative ranks, have not yet been proven, or distinctly identified [30, 33]. In this regard, it is of undisputed interest to set and perform a number of research tasks, among which the most crucial are the following: 1) to define the patterns of contact between English and the heterogeneous group of the genetically distant autochthonous languages of East Asia; 2) to identify the typology of phonetic variation in the speech of East Asian-English bilinguals (through the prism of cognitive processes occurring when acquiring the sound system of the second language; also considering features of late bilingualism, as well as a general course of native and non-native language evolution in an individual, etc); 3) to draw the effortful listening models reproducing the perception of East Asian-accented speech (including the description of mechanisms of perceptual adaptation to accent variability), and others. The results of such an interdisciplinary multitargeted research are greatly desirable in view of the necessity to reconsider the methods of teaching English as the language of international communication in APR, taking into account its de facto linguistic diversity (namely, its phonetic and phonological variability). It is vital to train highly competent interpreters and professionals in regional and international relations, who will be further employed at the Far Eastern labor market, therefore, contributing to the successful integration of the Russian Far East into the APR, and, hence, interpenetration of national cultures — Russian, European and East Asian.

## 2 An evolutionary approach to language modeling. Model idea

Specialists in the field of linguistics distinguish a hierarchical structure consisting of elements (language units) with various functions and properties in a natural language. The same elements are found in the speech of different speakers of the language, which determines their linguistic community. Acquiring a native or non-native (second / foreign) language, a language user reproduces elements and higher-order structures consisting of those smaller units, found in the speech of other members of the relevant language group. This reproduction does not mean exact copying, but implies some modification that eventually brings noticeable changes in the language (*cf.* ancient Russian and modern Russian). Based on these prerequisites, the authors of the study consider it possible to apply an evolutionary approach to the modeling of language processes, both on a large time scale and on a small scale.

The modeling of the communicative process in a group of language speakers can be attributed to the direction of evolutionary modeling "Artificial Life". There are many computer models of the so-called "Artificial Life" [1, 7, 19, 20, 27, 28, 34, 38]. The general idea of computer simulation of evolution comes down to creating a

population of agents that have the property of reproduction, as well as a set of some other properties that determine their behavior. Among such properties may be the following: the ability to acquire and lose some resource (the ability to feed and expend energy), the ability to receive signals from the environment, including those from other agents, the ability to act on the basis of these signals, the ability to analyze signals from the environment and make decisions about follow-up actions based on this analysis, etc. There are many studies in this area that simulate certain aspects of the evolutionary process, such as changes in food resource volume, the presence of motivation for various actions (energy accumulation, reproduction, etc.), the coexistence of competing groups, the coexistence of groups in the predator-prey model, etc.

We define the natural language of the species as a means of organizing and transmitting information within the group of individuals of this species. The idea behind the model is that a language can be represented as a resource consisting of a set of structural elements distributed in a group of language speakers, as shown in Figure 1.

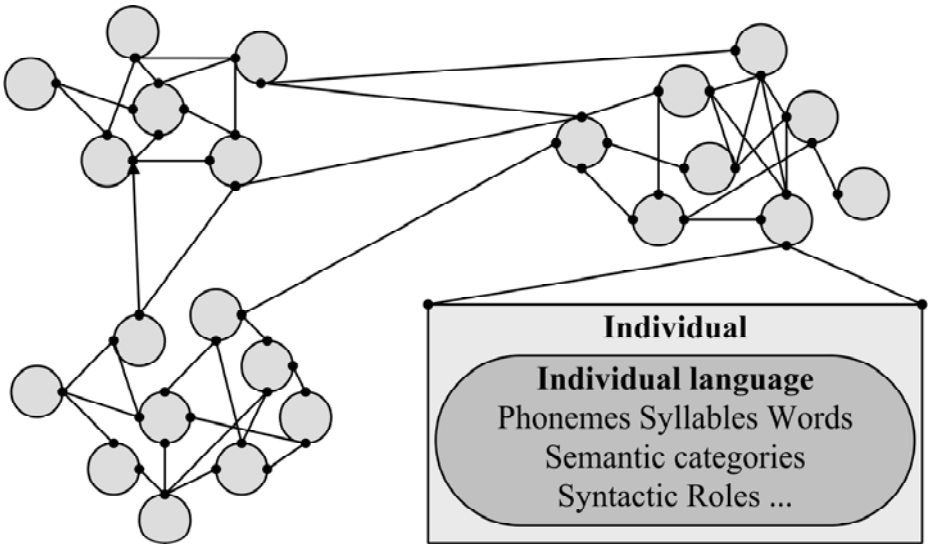


**Figure 1.** The scheme of interrelations in the group of language speakers, where the language is represented as a distributed resource

As a result of communication, the resource is redistributed, with more copies being created for some elements than for others, as a result of which selection occurs. If an individual speaks several languages, the linguistic systems interfere with each other; thus, elements of one language can be replaced by elements of another, or mistakenly recognized.

The developed software system is a simulator of a commutative process with variable parameters. The basis of the work of the PS is a mathematical model of the subject area, describing the data and laws in a form in which they can be translated into program code. To solve the task, an ontological approach was chosen. It allows

you to get the necessary transparency of the model and implementation, which in turn makes it possible to discuss the model with a wide range of subject matter experts, make necessary adjustments and take proposals into account.

## 3 Modeling the structure of a language with regard to the dichotomy of language and speech

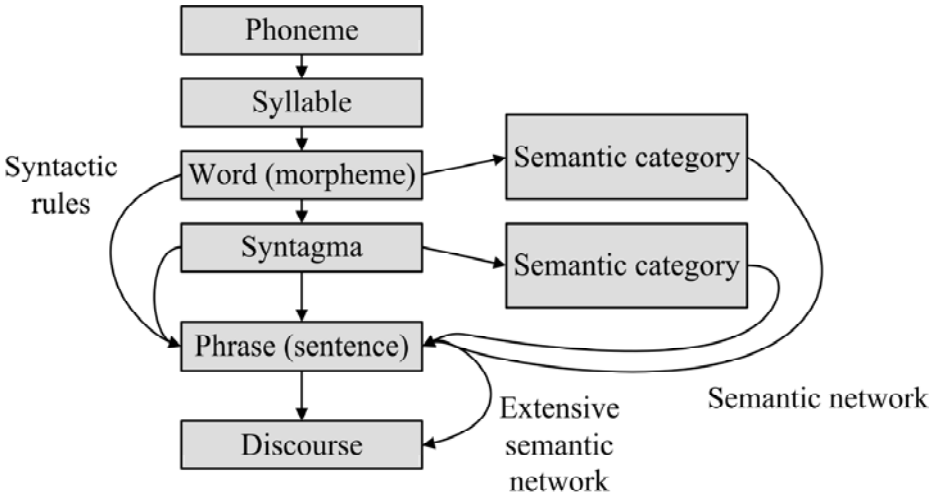


**Figure 2**. Scheme of language / speech organization

In accordance with the ideas of specialists in modern acoustic phonetics and phonology, human speech is a sequence of sound signals with different spectral characteristics. The minimal segment of speech signal is considered to be the phone — a sound that has unique individual characteristics distinguishing it from other phones. In view of speech-language dichotomy, the phone as a minimum speech segment correlates to the the phoneme as a minimum abstract sound unit of a language.

Unique phonemic sequences, through syllables (irregularly in phonemic languages, regularly in syllabic ones), encode semantic units, which in turn are combined into syntactic sequences correlated with semantic categories, as shown in Figure 2.

For our software system, we have identified the following categories of speech-language elements:

- Phoneme — the minimum abstract linguistic unit that is realized via phone in speech signal.
- Syllable — a sequence of phonemes. A syllable is such a sequence of phonemes that is valid. There exist sequences of phonemes (two or more phone segments) that are not syllables.

- Word (or morpheme) — syllable sequence that is associated with meaning. The word (morpheme) may be equal to a syllable or may include several syllables. A set of words is a subset of valid syllable sequences. There exist sequences of syllables that are not words — pseudowords.
- Syntagma (= phrase as a grammatical unit) a sequence of words. A syntagma can be equal to a word or it can include several words. A syntagma is considered such a sequence of words that is valid. There exist sequences of words that are not syntagmas.
- Phrase (= sentence as a grammatical unit) is a sequence of syntagmas. Phrase (sentence) is considered such a sequence of syntagmas, which is valid. There exist sequences of syntagmas that are not phrases (sentences).
- Acoustic-articulatory pattern — a phoneme or syllable parameter (phoneme combination), which characterizes the relationship of a language unit with other units that have this parameter. The set of all available parameters in the language is a list of acoustic-articulatory patterns, an unordered set.
- Syntactic category — a word, syntagma or phrase (sentence) parameter characterizing the relationship of a language unit with other units that have this parameter. The set of all available parameters in the language is a list of syntactic categories (conditionally, parts of speech or syntactic constructions), an unordered set.
- Semantic category — a parameter of a word (morpheme), a syntagma or a phrase (sentence), which characterizes the relationship of a language unit with other units possessing this parameter. The set of all available parameters in the language is a list of semantic categories (conditionally meanings), an unordered set.

Speech-language elements in the model are combined in a hierarchical structure, where each next element consists of some sequence of simpler elements. In this case, not all sequences of elements are valid, which models syntactically and semantically understood speech.

According to modern studies, acquiring a foreign language in adulthood takes place using the same mechanisms that are involved in children [14]. With the presentation of a new word (or pseudo-words), a memory trace is formed in the brain (a group of neurons that reacts to the presentation of an appropriate stimulus). Each new appeal to the formed memory trace activates it and increases the efficiency of the response. In this case, the activation of the memory trace associated with a word occurs not only with active use (pronouncing the word), but also with the passive presentation of the word, even when the listener does not focus his/her attention on it [25].

In order to simulate this process, in the individual language (recognizable set of elements) of a language speaker, or the agent, we have identified a passive (understood) and active (used in speech) subsets, so that the active subset is included in the passive subset, and the passive subset is in turn included in the whole set of elements forming the individual language. The inclusion of a structural element of a language into one or another subset is characterized by the value of its presentation counter.

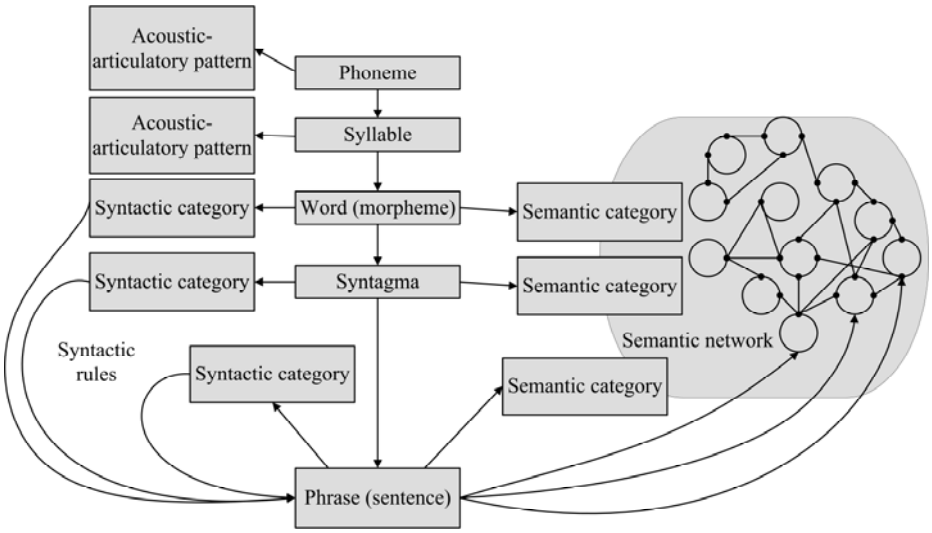


**Figure 3**. Scheme of speech-language organization in the model

In the model, the agent's language memory is a repository of data structures, which are a pair of "language element — entry counter".

Agents can communicate with each other — transfer a language resource to each other by copying, and thus acquire a language — accumulate a language resource. As a result of this process, the distribution of the language resource in the group is changed. A comparison of the distributions before and after simulation can give an idea of how certain factors influence the adaptation of language speakers to various communicative situations.

## 4 Simulation of speech recognition process

Speech recognition by the human brain is a complex, evolutionarily developed mechanism that allows an individual to decode a sound signal and relate it to the abstract semantic categories stored in memory. According to modern studies [3–6, 8–14, 16–18, 23–26, 29, 31, 32, 35–37, 39, 41–44, 46], speech signal processing is a process divided into two streams, each of which has its own specialization, as shown in Figure 4. These two streams in modern neuroscience are called dorsal and ventral. As a result of the primary processing of the auditory signal, the spectral and temporal characteristics are extracted and compared with the time grid, which leads to the division of sound into phonemes. In the dorsal stream, a sequence of phonemes is matched with articulation actions that would lead to the reproduction of these phonemes. In the modern view, this process is necessary for cleaning the noisy speech signal, as well as for learning new speech skills. One of the functions of the dorsal stream is the prediction of phonemic sequences, which, apparently, facilitates the extraction of the spectral and temporal characteristics of a speech signal by reducing the number of possible options for matching. In addition, the syntax processing

function is also associated with the dorsal flow (at least partially), since it is in the dorsal stream that the processing of sequences is implemented taking into account the order of presentation of elements. The ventral stream correlates with the display of the speech signal on the space of abstract semantic categories. One of the functions of the ventral stream is also the prediction of speech input, but not in the form of a phonemic representation, but in the form of a semantic graph. The result of this mechanism is a one-to-one mapping of the speech signal on the semantic network.

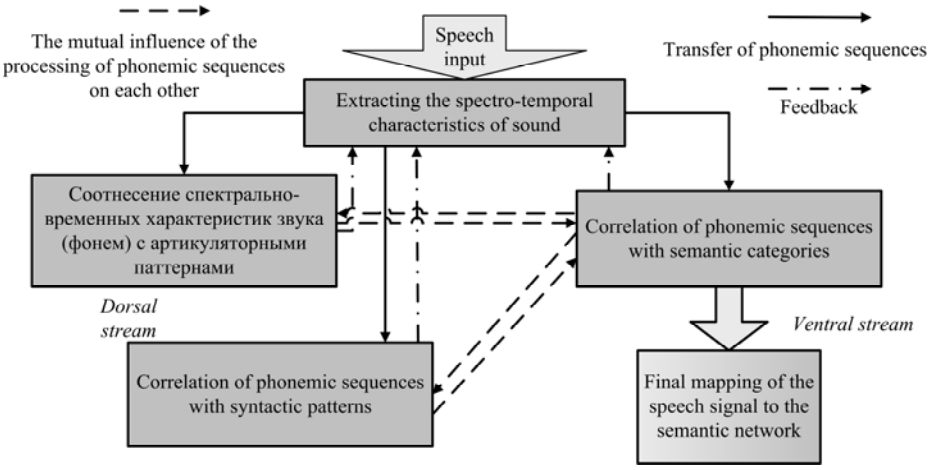


**Figure 4**. Conceptual diagram of the model of a two-stream processing of a speech signal

In the model, we ignore the spectral and temporal characteristics of the sound, setting the correlation of phonemes with articulatory patterns in an explicit form. Correlation of words and phrases with semantic and syntactic categories is also specified in an explicit form. The processing of a speech signal in a software system is divided into three "streams" — acoustic-articulatory, syntactic and semantic. Each "stream" is an algorithm for processing a phonetic sequence, but based on different systems of rules. In the acoustic-articulatory "stream", the phonemic sequence is matched with the acoustic-articulatory patterns, forming the acoustic-articulatory presentation of the utterance, in the syntactic "stream" a syntactic representation is formed, in the semantic "stream" — semantic. At each step of the "stream" operation, the forecast of the next element in the sequence is formed. This forecast is transmitted to other streams and influences the formation of each representation of the phonemic sequence accordingly. The final representation of the phonemic sequence determines the degree of understanding of the received message by the agent.

## 5 Model of distortions caused by interference

According to existing research, in the English speech produced by a native speaker of the East Asian languages (EA bilingual), the phoneme can be:

- Pronounced according to the statistical standard of the English language;

- Replaced by another (analogue in the native language, or allophone);
- Replaced by phoneme string (+ segmentation);
- Deleted (– segmentation).

Correct (corresponding to the statistical standard of the English language) realization of phonemes in English speech produced by EA bilingual depends on:

- The presence of an acoustically identical phoneme in the native language (if such a phoneme exists in the native language of a bilingual, it will be used with high probability).

The replacement of the phoneme in English speech produced by EA bilingual depends on:

- The presence of an analogue of this phoneme in the native language, in case the phoneme itself is absent (the analogue from the native language will be used with high probability);
- Neighboring phonemes (a phoneme can be replaced with another one if the production of such an option requires less articulatory effort than the correct one);
- Allophone distribution in the native language (instead of the correct phoneme, an allophone from the native language, not accepted in English, can be used).

Removing a phoneme in English speech produced by EA bilingual depends on:

- The presence of this phoneme in the native language (the phoneme can be deleted if it is not present in the native language of EA bilingual);
- Neighboring phonemes (a phoneme can be deleted if pronouncing such an option requires less articulatory effort than the correct one).

The addition of phonemes in English speech produced by EA bilingual depends on:

- Neighboring phonemes (a phoneme can be added if pronouncing this variant is less effortful than the correct one).

The word (or sentence) stress in English speech produced by EA bilingual can be:

- Delivered correctly;
- Transferred to another syllable;
- Put on the right syllable and on another syllable, which is unstressed in standard pronunciation;
- Transferred to several other syllables, which are unstressed in standard pronunciation;
- Deleted.

As a result, there is a violation of the spectral and temporal characteristics of the speech signal, which leads to failures in recognition. A more detailed description can be found in [40].

In order to implement this process in the model, let us assume that there exists some kind of standard (typical / reference) representation of a language — such a subset of elements possessed by the agents associated with native speakers of a given language and with bilinguals possessing the structure of the given language (used by them as a lingua franca in certain communication contexts) at high level. Another group of agents associated with late bilinguals, having medium and low level proficiency in the given language (used by them as a lingua franca in certain communication contexts), are considered to only partially possess the above-

described subset of the standard (typical / reference) representation of the given language. Missing elements are replaced in it with the elements of the subsets existing in these agents' native language.

## 6 Simulation of the communicative process in a heterogeneous group

In the model of the communicative process, there are three important phases:

1. Generation and transmission of the message;
2. Receiving and decoding a message;
3. Feedback.

Let us consider these phases in more detail.

Message generation is the formation of such a sequence of language elements from a subset of the active (used in speech) agent language, which follows the syntax rules of the active agent language and corresponds to the connections in its semantic network. During the transmission, the message may be distorted, for example, in case a noisy communication channel is used.

Decoding of the received message takes place on the basis of a subset of the passive (understood) agent language, as a result of which an understanding coefficient is calculated. The continuation of the communication process between agents depends on the value of the coefficient.

In the course of the communicative process, agents "acquire" the language of each other — they copy and accumulate a language resource from each other's subsets.

In addition to the language resource, agents in the model may have such parameters as the desire for new communication links, the desire to maintain the current communication link, the desire to maintain communication links with those agents for whom a high coefficient of understanding is obtained, etc. This will give us the opportunity to simulate various communication situations.

## 7 Scheme of the software system

Figure 5 shows the design of the simulator.

The main element of the simulator is a step-by-step module of the communicative process. It employs two key submodules implemented for each agent: an input speech signal generator and a decoder that works on the principle of three-stream processing.

The generator uses a model of foreign-accented speech, developed by V.L. Zavyalova [47]. The model describes the configuration of changes that occur in English speech produced by EA bilinguals as a result of phonetic interference (i.e., mutual influence of the phonetic systems) of the bilinguals' native language (Chinese, Japanese or Korean) and their second (foreign) language (English).

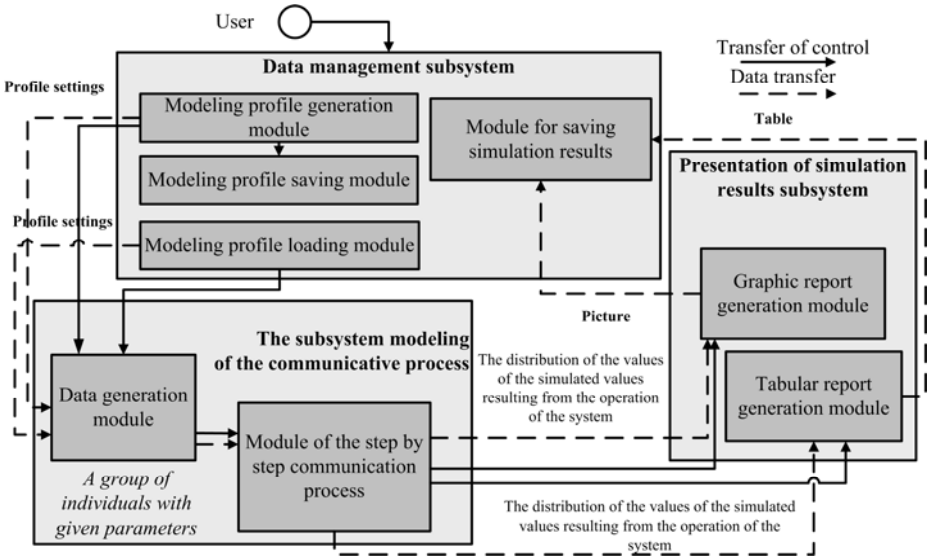


**Figure 5**. Architect-contextual diagram of the software system

To create a speech signal processing algorithm, an ontological model of the subject area is used, which describes modern ideas of specialists about the functioning of the human brain. As a result of the decryptor's work, the sequence of the input signals is displayed on the semantic network, which demonstrates the degree of speech understanding. Changing the parameters of the simulator will provide an opportunity to reproduce various communicative situations.

## 8 Conclusion

The developed software system is designed to simulate the process of speech production and perception with possible violations in context of non-native language communication. Variable parameters will allow reproducing various communicative situations, as well as different states of the speaker / listener, including conditions of his/her current subsets of elements in the given language, efficiency of mapping procedures and other recognition-related aspects. Attention is considered a key factor affecting successful recognition, as it can be directed to various facets of speech (phonological, semantic, etc.). In addition, speech signal noise and context awareness can play a significant role in communication.

Currently the software system is in the project development stage. After the completion of its implementation, it is planned to conduct model experiments that will demonstrate the degree of influence of various factors on the production and perception of speech with features of foreign accent. The project described forms an integral part of the comprehensive study conducted by the Department of Linguistics and Intercultural Communication, FEFU, the overall results of which will have

implications for the improvement of the real economy sector of the Russian Far East and Russia's interaction with neighbouring APR countries.

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