AUTOMATED TRANSLATION FROM INFLECTIONAL LANGUAGES TO SIGN LANGUAGES

Olexandr Barmak, Iurii Krak, Sergii Romanyshyn

Abstract: *The article describes the algorithmic implementation of information technology for translation from inflectional languages to sign language. For example info logical model of Ukrainian dictionary and sign language, related generalized grammatical constructions for automatic translation are built. The experimental results to verify the effectiveness of the proposed information technology are represented.*

Keywords: *Automated translation, sign language, inflectional language.*

Introduction and problem statement

The current state of the international community produces certain attitudes towards people with disabilities. The problem of increasing the degree of people with impaired hearing disabilities participation in society is of great importance. The main obstacle to resolving this problem is the difficulty in communication between people with impaired hearing and hearing people. One of the ways to solve this problem is to create an advanced information technologies for non-verbal communication. These areas of research are involved in many of the leading organizations in the world: the Zardoz system [Veale, 1998], ViSiCAST project [Marshall, 2003], system developed at Dublin City University [Morrissey, 2010], informational technology for non-verbal communication for people with impaired hearing [Krak, 2008].

Sign language is a natural language that conveys information through movements of hands and fingers, facial expressions, position of the body. It is used as part of communication for people and serves as the primary means of communication for people with impaired hearing. Sign languages are not the visual interpretation of ordinary language. They have their own grammar that can be used to discuss a variety of topics from simple and specific to the sublime and abstract. The lexicology, phraseology, morphology of sign language is still poorly understood.

The aim of this work is to develop informational technology of translation verbal inflectional languages to a natural sign language. When the data is translated from one language to another pair of grammatical constructions is obtained. These grammatical constructions convey meaning: sentences in the input language → appropriate sentence in the source language. We suppose that a pair of data structures can be represented as a certain generalization. By analyzing certain amount of pairs obtained by translation the word order in sentences can be fixed, and allow us to build a generalization, in which instead of specific words in the sentence we will get the set of words that can be used in these fixed locations. The amount of grammar constructions obtained this way is fairly small (relative to the total number of sentences).

We offer a solution to this problem with the following restrictions:

1) The system works only with simple sentences limited to a fixed list of topics and situations;

2) The system translates (with no subsequent corrections) only trained structures of sentences, without distorting the meaning; translation prediction is possible for other structures of sentences;

3) Permanent expansion of a list of translation structures is possible.

Models of dictionaries for automated translation

Automated translation from inflectional languages to sign language involves the creation of plural model for the dictionary of the language [Shirokov, 1998] for modeling of generalized grammatical constructions of inflectional and sign languages.

In inflectional languages grammatical meaning are transmitted through flexions. The words of inflectional language are modeled as a combination of two components: constant component (base) and a variable component (flexion).

$$x = c(x)\,\&\,f(x), \quad (1)$$

where $c(x)$ – constant part of lexeme x, $f(x)$ – variable part of lexeme x, & – concatenation.

Inflectional languages have a formal model of inflection. An inflection expresses one or more grammatical categories with a prefix, suffix or infix, or another internal modification such as a vowel change. Inflexion expresses different grammatical categories such as tense, mood, voice, aspect, person, number, gender and case. Considering these features of inflectional languages words are modeled as:

$$W = \{W_i : W_i = \{I_{i_1} \in I, F_{i_2} \in F,\, k,\, In_{i_3} \in In\}\} \quad (2)$$

where W_i are parameters of inflectional language ($i = 0,\cdots,N-1$, N – amount of words in dictionary); F – set of all possible flexes; k – position in base word form, from which it is concatenated with flexion ($k = 0$ – if inflected word if completely different from base word form); In – set of inflectional parameters of a language (tense, mood, voice, aspect, person, number, gender and case), I - a set of base word forms:

$$I = \{I_i : I_i = \{word\,\text{inf}, p \in P\}\} \quad (3)$$

where P - a set of parts of speech; $word\,\text{inf}$ - base word form.

Sign language dictionary structure is simpler due to the absence of inflection in it. In non-verbal communication mimic component plays a very important and sometimes crucial role. It should be noted that the syntax of sign language is characterized by non-manual marker: the questioning sentences with general questions – raising eyebrows; in a separate (private) question – omission of eyebrows and head tilted forward; in denial – negative head movements, the corresponding expression; in narrative sentences it is characterized by facial emotional color that corresponds to the meaning of the information transmitted.

The set of gestures is modeled as:

$$Ges = \{Ges_i : Ges_i = \{word\,des, pges \in PGes, em \in Em\}\} \quad (4)$$

where $word\,des$ – description of gesture, $PGes$ – corresponding part of speech, $Em \in \{em_1, em_2, em_3\}$ – a set of emotional coloring: em_1 .– narrative emotion, em_2 .– questioning emotion, em_3 – other emotions.

Models of grammatical constructions for automated translation

Will consider the syntactic features of sign language using three typical structures of sentences: subject-object-verb, subject-verb-object, verb-subject-object. Subject and predicate in these proposals are related by predicative bond. We define simple sentences as sentences that have one predicative bond. Note that the order of words in sentences with one predicative connection in most spoken languages of the world is described by one of three types of structures [Tomlin, 1986]. In sign language simple sentences serve as the primary means of communication and are divided into declarative, interrogative and incentive.

Sentences								
1	2	…	n	→	k1	k2	…	km
Word	Word		Word		Gesture	Gesture		Gesture

↓

Grammatical constructions								
1	2	…	n	→	k1	k2	…	km
{Set of words}	{Set of words}		{Set of words}		{Set of gestures}	{Set of gestures}		{Set of gestures}

↓

Generalized grammatical constructions								
1	2	…	n	→	k1	k2	…	km
([±]PP, [±]II), [±]V	(…)		(…)		([±]PP)	(…)		(…)

Figure 1. Building generalized grammatical constructions

After building the inflectional and sign language dictionaries we need to build a model of grammatical constructions of sentences. By sentence will understand the sequence of words and punctuation (fig. 1). We consider working only with simple sentences (any complex sentence can be represented as a composition of simple sentences). By grammatical sentence construction we understand the sequence of words of language relating to parts of speech that convey meaning (we discard function words as they don't convey meaning). We distinguish grammatical constructions by the number of words they contain. Grammatical constructions (as opposed to sentences) contain the set of words that meet in certain position of sentences:

$$Gr = \{Gr_i = \{word_j \in W \| seq_j \in Seq \| p \in P,\ In_{i_1} \in In, num\},\quad GStr_i = \{ges_j \in Ges \| gseq \in Gseq \|\ pges \in PGes, num, gesnum\}\} \qquad (5)$$

where *num* – number of element in structure of inflectional language, *gesnum* – number of element in structure of sign language, In - set of inflectional parameters of a language, *P* – a set of parts of speech of inflectional language, *PGes* – a set of parts of speech of sign language, *W* – a set words of inflectional language, *Ges* – a set words of gestures,

$$Seq = \{Seq_i : Seq_i = \{word_j \in W : word_j \in W, n\}\},$$

where *n* – number of word in set of words,

$$Gseq = \{Gseq_i : Gseq_i = \{ges_j \in Ges : ges_j \in Ges, n\}\},$$

where *n* – number of gesture in set of gestures.

After receiving a set of grammatical constructions we analyze each of the sets of elements that go into it. By generalized grammatical constructions we understand a construction that contains a combination of inflectional parameters of a language instead of set words:

$$GGr = \{GGr_i = \{p_j \in P, In_j \in In, num\}, \quad GStr_i = \{pges \in PGes, num, gesnum\}\} \qquad (6)$$

Generalized grammatical constructions can contain parameters which may or may not be used at certain sentence position, such as part of speech $PP = \{PP_i : PP_i = \{p_i \in P\}\}$ and inflectional parameters of word (depending on language specification it can contain tense, mood, voice, aspect, person, number, gender and case) $II = \{II_j : II_j = \{In_j \in In\}\}$. In addition to inflectional parameters generalized grammatical constructions can also contain set of certain words $V = \{V_i : V_i = \{w_i \in W\}\}$.

Translation algorithm

The following algorithm (fig. 2) for automatic translation from the inflectional language to sign language is proposed:

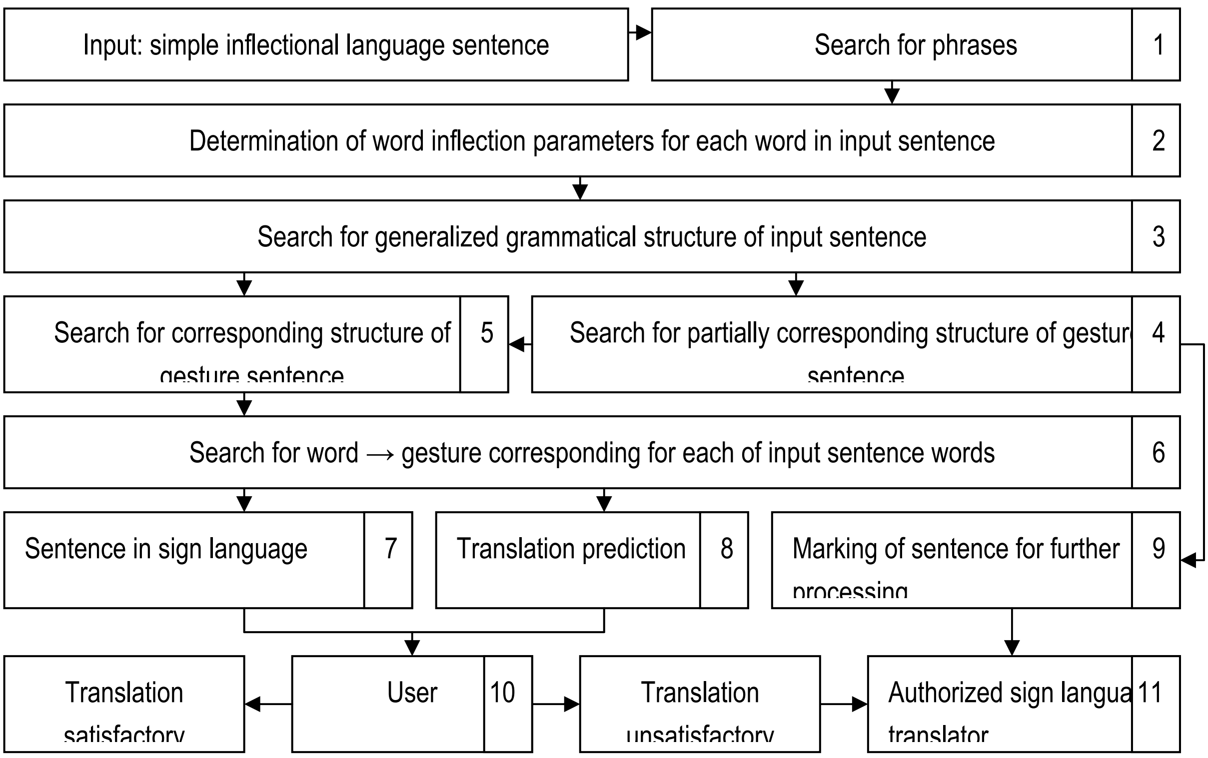

Figure 2. Automated translation algorithm

1. Input sentences are checked for existence of phrases.

2. Using inflection language vocabulary inflection parameters for each word are determined.

3. Based on inflection parameters the generalized grammatical construction is determined.

4. If generalized grammatical construction if not found the search of partially corresponding constructions is performed.

5. If generalized grammatical construction of input sentence is found we determine corresponding generalized grammatical construction of gesture sentence and gestures corresponding to input words.

7. If the corresponding generalized grammatical construction and corresponding gestures are found.

8. In case if partially corresponding grammatical construction an attempt to predict translation is made.

9. If no partially corresponding grammatical construction is found the sentence is marked for further processing by authorized sign language expert. The expert can create new grammatical constructions or corresponding between words and gestures.

10. After receiving the translation user chooses one of the following:

- The translation is satisfactory and is stored to statistical database as correct;
- The translation is unsatisfactory and is stored to statistical for further processing. The result of translation can be manually edited.

Creation of the automated translation system

To implement the proposed approach, on an example of the Ukrainian language, a set of gestures and a set of sentences used in everyday communication were formed based on the educational program of the "Ukrainian Sign Language" which is used in schools for the people with impaired hearing to master sign language. Sentences were translated to sign language with the help of sign language experts. Each of the sentences was put in correspondence sign language sentence. The sentences in the data model were merged into the grammatical constructions obtained by generalization according to the formula (5). For example sentences “He walks”, “She walks”, “Man walks”, etc were merged into grammatical construction “{He, She, Man…} walks”. By analyzing the sets of words on their inflectional parameters generalized grammatical constructions were built according to the formula (6). For example set of words in first position of grammatical structure “{He, she, man…} walks” contains only singular pronouns and nouns in masculine and the feminine gender in nominative case followed by singular verb in present tense. Based on that information generalized grammatical construction which contains singular numerals and nouns in masculine and the feminine gender in nominative case on first position and singular verb in present tense in second position is built.

Discussion

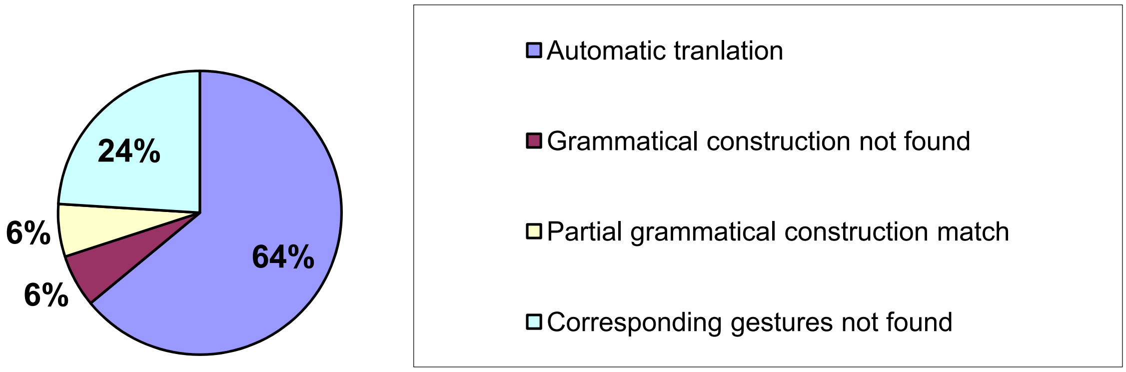

Figure 3. Automated translation system testing results

Using the proposed technology a dictionary of 2 millions words (140 thousand base word forms and 2 thousands flexes) of Ukrainian language was built. Based on the educational program of the "Ukrainian Sign Language" used in schools for the people with impaired hearing to master sign language the set of 10 thousand sentences and a set of 3 thousand gestures were formed. As a result 300 generalized grammatical constructions were built. To test the technology 500 simple sentences were taken from periodical literature for people with impaired hearing. As a result (fig. 3), 64% of sentences were translated automatically, 24% were not translated due to lack of word → gesture corresponding, 12% were not translated due to absence of generalized grammatical constructions (for 55% of these sentences generalized grammatical constructions which partially correspond to sentence were proposed).

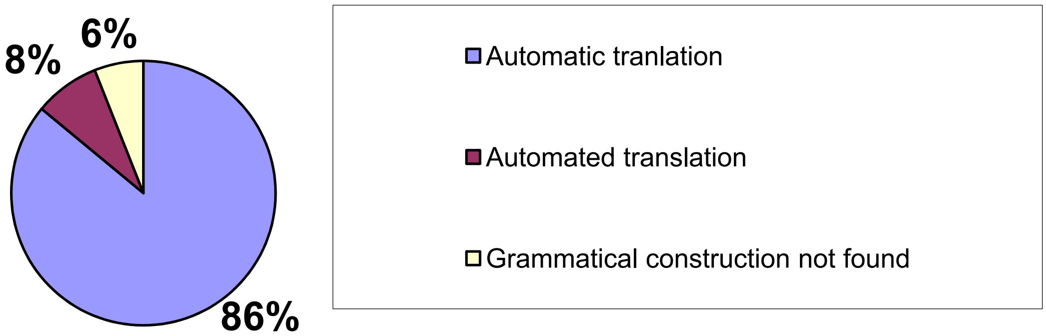

Figure 4. Automated translation system testing results with updated gesture dictionary

After adding the lacking word → gesture dependences we got the result (fig. 4) of up to 94% satisfactory translations (86% automatic and 8% automated translation based on partially corresponding grammatical constructions).

Further research aims to specify satisfactory gesture vocabulary based on corpus of texts used by people with impaired hearing in everyday communication and update generalized grammatical constructions list based on testing results.

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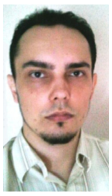

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