Translation of Natural Speech into Sign Language Based on Semantic Relations

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Abstract

Based on speech observations in children and categories of semantic classes we designed a system which identifies these in natural language and translates them into a sign language. To accomplish this translation, we use algorithms to annotate a set of semantic relations in children's language and hope to regain these sentences from natural source sentences. We define a set of rules used to change the word sequence of origin sentences at every marked relation.

1. Introduction

The paper describes the extraction of semantic relations in natural language based on syntactic and morphologic data we collect of language in children. This information exercises and improves the translation of language, here German, into sign language. Motivation is the assumption that semantic relations of the source language are more relevant than syntax for the arrangement of words and phrases in a target language for expressing equivalent information.

The syntax of sign languages differs considerably from the syntax of natural language sentences. It is often assumed that there are fewer, if any, grammar rules for sign languages. Each speaker follows his or her own grammar rules. The term "sign language syntax" is very speaker-dependent.

2. Processing

2.1. Child language

First, children's oral speech between birth and the first day at school is monitored (Stern and Stern, 1928). During development, the syntactic, morphologic and lexical abilities of the children are observed and thus the semantic categories the children are able to differentiate between is learned.

When the first steps to express wishes and feelings were observed, we recognized that the use of syntax rules are quite similar to sign language. At the age of seven, a child controls 15 base and main relations (Szagun, 1980). We isolated these relations and their typical syntacto-semantic realizations.

Two Examples with syntacto-semantic annotation:

Semantic Relation	*Examples*	*Annotation*
Handlungsrelation/ action relation	Er fährt Zug. '*he goes-by train*'	Subject, Object, Action – Verb
Lokative Handlungsrelation/ locative action relation	Er fährt nach Hause. '*he rides home*'	Subject, Object(Dativ), Action – Verb

2.2. Machine learning

In the second step a system is designed which focuses on the grammatical abilities of humans at seven years of age. A classifier is trained to extract the semantic relations, subject, object and direction of verb based on features such as part-of-speech verb type (Rudolph and Försterling, 1997), gender, case, tempus, numerus, mode and verb frames (Schulte, 2003). The lexicon is limited to the oral vocabulary of first to second grade children (Pregel and Rickheit, 1987).

Only non-complex sentences up to a length of 10 words and only one strong relation per sentence have been considered so far.

Semantic categories the automat must recognize are the three base relations presence, not-presence and again-presence. It's a necessary minimum to create new word sequences. Classification process is not bound to verb characteristics as action or state.

Semantic Relation	*Examples*
Vorhandensein/ presence	Oma ist am Fernseher. / Grandma is at the window. Papa liest ein Buch. / Dad reads a book.
Wieder-Vorhandensein/ again-presence	Ich will noch einmal. / I want again. Er fährt und fährt und fährt. / He drives and drives and drives.
Nicht-Vorhandensein*/ not-presence	Ich weiß nicht./ I don't know. Niemals!/ Never!

*Nicht-Vorhandensein/ not-presence implicates statements such as *denials* and *refusals.*

An more exactly assortment becomes possible, if we are able to split into another main relations.

The question– and intention–relation we separate to question- or w–question- relation and intention- and imperative–relation.

Examples:

Semantic Relation	*Examples*
Handlung/ action	Lisa rennt./ Lisa runs.
Lokative Handlung/ locative action	Lisa rennt nach Hause./ Lisa runs home.
Zustand/ state	Er ist rot./ He is red.
Lokativer Zustand/ locative state	Oma ist am Fenster./ Granny is at the window.
Intention/ intention	Ich will spielen./ I want to play.
Imperativ/ imperative	Lauf!/ Run!, Anne muss es tun./ Anne must do it.
Instrument/ instrument	Mit einem Messer schneiden./ Cut with a knife.
Dativ/ dative	Mama malt mit Anne am Computer./ Mum paints with Anne at the computer.
Handlung und Ort/ action and location	Ich lese im Buch./ I read in the book.
Bemerken/ recognize	Da sind Peter und Paul./ There are Peter and Paul.
Besitz/ Possession	Hans hat einen Hund./ Hans got's a dog.
Nachträgliche Bemerkung/ Addition	Oder es raschelt in der Wohnung./ Or it rattles on the roof.
Frage/ question	Seid ihr da?/ There are you?
W – Frage/ w-question	Wo seid ihr?/ Where are you?

For every relation we define one of these options:

- exists an explicit template for the target language
- exists a rule to insert one or more elements into another templates

As soon as we know contained relations, we start to identify contained constituents. Constituents are the atomically parts for rearrangement of sentences.

During analyzing sentences of child speech we noticed it's sufficiently to search for subject, verb, time, location, interjection, question word, negative and repeat particles. Another parts are quite rare, so we label these as objects.

We use some known techniques and tools To recognize constituents. Most of them are included in TNT–Tagger package.

2.2.1. Subject

We annotate sentences and marks contained subjects. Automat learns recognize subjects through tagging sentences, subjects and subject-frames (right and left neighbors). In later runs the automat is able to expand his knowledge to unknown sentences and sentence – structures.

2.2.2. Time constituents

The syntactic function of time constituents are similar to subjects. We can not define a set of preferred part-of-speech. Therefore we use again tags and frames of the annotated train corpus. Some words occurred more frequently in time frames. To support tagging we create a list of known time constituents.

2.2.3. Locative Constituents

Locative Constituents are often bound on appearing of prepositions. We observe prepositions of the train corpus and notice the neighbored words and tags.

2.2.4. Verb

Verb–recognition is a directly result of part-of-speech–Tagging. Usually verbs are labeled with standard tags or combinations.

Verb – Tag Examples	*Examples*
VVFIN	Gehst du jetzt?
VVIMP	Geh!
VVINF	Wir wollen gehen.
VVFIN + PTKVZ	Gehst du jetzt weg?
PTKZU + VVINF	Sie stand auf, um zu gehen.

2.2.5. Interjections

Interjections are marked too while part-of-speech – Tagging. Examples: Ah, oh, ieh.

2.2.6. Question words

Question words are question-introducing words beginning with character w. Therefore the relation is called w–question. The few existing question words the POS–Tagger recognize as interrogative pronouns. By taking the tagged pronouns at the beginning of sentences we got a list of question words.

Fragewort	*Examples*
was (Tag: PWS)/ what	Was tust du?/ What you are doing?
welche (Tag: PWAT)/ which	Welche Farbe ist das?/ Which color is it?

2.2.7. Negations

A negation becomes expressed only with a small number of words. Examples: Nein, kein, nicht/ no, not.

A negation is an indicator of an not–presence–relation.

2.2.8. Repeat

Similar to negations can we find particles of repeating, for example: schon wieder, noch einmal/ (already) again. Particles of repeat helps identifying again–presence–relations.

2.2.9. Object (or each other)

For the moment we are labeling all parts of speech as object, which was not tagged as Subject, time, locative, verb, interjection, question word, particle of negation or repeat.

2.3. Rearrangement of words

The third step is to find regularities in the order of the target sentence by considering German sign language standards and research (Prillwitz and Vollhaber, 1990) of the German sign language. The transformation rules are assigned to the semantic categories determined before. The rules of each category are stored in rules of a context sensitive grammar. During a translation the system analyzes a sentence, recognizes the relevant semantic relation, subject, object and direction of verb and yields a suggested translation after applying the transformation rules. This suggested translation fills the category template.

This rearranged sequence can be improved with the aid of an appropriate dictionary. Dynamic(al) dictionaries, which contain an animation, e.g. 3D animated DGS (Deutsche Gebärdensprache/German sign language), can use the suggested translation. For static dictionaries, e.g. PCS (Picture Communication Symbols/ Mayer-Johnson), sequences of subject and object are dependent on verb direction.

2.4. Addition

While processing we looked at simple cases of sentences. Some important (and necessary) parts of analyze are not discussed. Two short examples:

Two or more neighbored words are strong similar and therefore one or more are redundant.

INPUT	Ich esse ein Essen./ I eat a meal.
-> reducing number of words	Ich esse./ I eat. {ich}{essen}/ {i}{eat}
-> translate to target language -> PCS	 or  ?

Compounding New Items (Klima and Bellugi, 1979): Two or more words are part of a new or known sign.

INPUT	Ich öffne ein Fenster./ I open a window.
-> compounding	{ich}{fenster-öffnen}/ {i}{window-open}

INPUT	Ich esse Frühstücke./ I eat breakfast.
-> compounding	{ich}{frühstück-essen| frühstücke}/ {i}{breakfast-eat}

3. Examples

{*} means *dictionary entry*, (*) means *mutely*, *|* means *or*

3.1. Animated Dictionary (e.g. DGS)

Semantic Relation	*Speech*	*Trans.Suggestion*
Handlungsrelation/action relation	Er fährt Zug.	{er} {zugfahren|Zug fahren}(.)
	Er fährt morgen Zug.	{morgen} {er} {zugfahren|Zug fahren}(.)
Frage-Relation/question relation	Wie ist dein Name?	{du} {Name} (ist) {wie}(?)

3.2. Symbol Dictionary (e.g. PCS)

Semantic Relation	*Speech*	*Trans.Suggestion*
Handlungsrelation/action relation	Ich rufe dich.	{ich} {du} {rufen}(.)[1]
	Ich lade dich ein.	{du} {ich} {einladen}(.)[2]

[1] *rufen:* left->right direction
[2] *einladen*: right->left direction

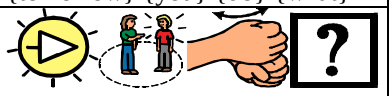
Example for minimum categorisation:

STEP	
INPUT	Ich will kein Gemüse./ I do not want vegetable.
-> identify Semantic Relation	Nicht-Vorhandensein/
-> analyze parts of sentence	Ich[Subject/ subject] will[Modaleverb/modal verb] kein[Negationspartikel/ particle of negation] vegetable.[Objekt/ object] .[]
-> choose template	{NEG} {SUBJECT} {OBJECT} {VERB}
-> insert base forms	{Nein|nicht|kein} {ich} {Gemüse} {wollen}/ {No|not}{i}{vegetable}{want}
-> translate to target language -> PCS	

Examples for optimum categorisation:

STEP	
INPUT	Ich habe gestern im Wald eine Blume gepflückt./ Yesterday I picked a flower in the forest.
-> identify Semantic Relation	Lokative Handlungsrelation/ locative action relation
-> analyze parts of sentence	Ich[Subject/ subject] habe gepflückt[Handlungsverb/action

	verb] gestern[Zeitkonstituente/ time constituent] im Wald[Ort/ location] eine Blume[Objekt/ object] .[]
-> choose template	{TIME} {LOCATION} {SUBJECT} {OBJECT} {VERB}
-> insert base forms	{gestern} {Wald} {ich} {Blume} {pflücken}/ {yesterday} {forest} {i}{flower} {pick}
-> translate to target language -> PCS	

STEP	
INPUT	Was machst du morgen?/ What do you do tomorrow?
-> identify Semantic Relation	Frage-Relation mit Handlung/ question relation with action
-> analyze parts of sentence	Was[Fragewort/ question word] machst[Handlungsverb/action verb] du[Subjekt/ subject] morgen[Zeitkonstituente/ time constituent] ?[Fragezeichen/ question mark]
-> choose template	{TIME} {SUBJECT} {VERB} {QUESTION WORD}
-> insert base forms	{morgen} {du} {machen} {was}/ {tomorrow} {you} {do} {what}
-> translate to target language -> PCS	

4. Conclusion

For the moment we can put all simple sentences into one of the existing templates as shown above. As a result translations of discussions between children are possible. Future questions we hope to answer which relate to adult speech are:

- How can we automatically create Meta templates from the described base relation?
- How can we merge the rule sets of two or more semantic relations?
- Can we split one sentence into many sentences with one relation?

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