Building a Generator for Italian Sign Language

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Abstract

This paper presents an ongoing work about the implementation of a CCG grammar for Italian Sign Language. This grammar is part of a generation system used for Italian-LIS translation.

1 Introduction

Italian Sign Language (Lingua Italiana dei Segni, henceforth LIS) is the sign language used by the Italian deaf (signing) community. LIS is a natural language that has a specific lexicon, morphology and syntax (Volterra, 2004). In the last years the computational linguistic community showed a growing interest toward sign languages (SLs), and a number of projects concerning the translation into a SL have recently started. Some of these projects adopt statistical techniques based on developing parallel corpora: English to Irish SL (Morrissey et al., 2007), Chinese to Chinese SL (Su and Wu, 2009). Some other projects adopt symbolic techniques: English to British SL (Bangham et al., 2000), English to American SL (Zhao et al., 2000; Huenerfauth, 2006). Recently a new project started for automatic translation from Italian to LIS: in this paper we present some features of the generation module adopted for the interlingua translation in this project.

The challenge of Italian-LIS translation depends on the complexity of the translation task as well as on the peculiar features of the LIS. Sign languages mix standard linguistics of vocal languages with a number of typical phenomena. Among others: there is a "spatial organization" of the sentence that interacts with the word order to determine syntactic/semantic dependencies and plays a role in the coordination; the presence of many articulators (two hands, eyebrow, eye gaze, torso etc.) allows for some form of parallelism; there are no prepositions, articles; finally, LIS is a poorly studied language and linguists often do not agree on basic linguistic properties (e.g. sentence word order). In order to reduce the difficulties of our ambitious project we concentrate on a specific application domain, i.e. weather forecasts. As starting point, the project is producing a parallel corpus of Italian-LIS sentence extracted from TV news and concerning weather forecasts.

Our interlingua[1] translation system has four distinct modules, that are: (1) a dependency parser for Italian; (2) an ontology based semantic interpreter; (3) a grammar based generator; (4) a virtual actor that performs the synthesis of the final LIS sentence. Here we give some details about the parser and the semantic interpreter, in the Section 2 we describe the generator.

In the first step, the syntactic structure of the source language is produced by the TUP parser (Lesmo, 2007). It uses a morphological dictionary of Italian (about $25,000$ lemmata) and a rule-based grammar. The final result is a *dependency tree*, that makes clear the structural syntactic relationships occurring between the words of the sentence (Hudson, 1984). Each word in the source sentence is associated with a node of the tree, and the nodes are linked via labeled arcs that specify the

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[1] Our system can be defines as a knowledge based restricted interlingua, since it uses extra-linguistic information and deals with just two languages (Hutchins and Somer, 1992)

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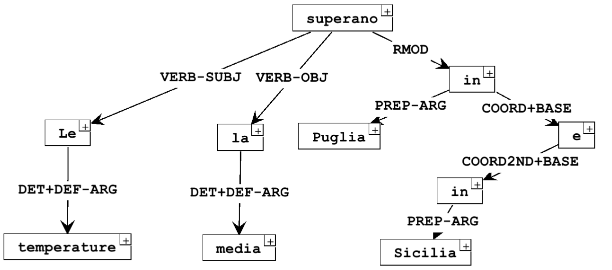

Figure 1: The syntactic structure of the sentence "Le temperature superano la media in Puglia e in Sicilia" (*The temperature exceeds the average in Puglia and Sicilia*).

onto(l_1:*meteo-status*,**exceed**)	event(e_0,l_1)
onto(l_2:*eva-entity*,**temperature**)	agent(l_1,l_2)
onto(l_3:*eva-entity*,**average**)	theme(l_1,l_3)
onto(l_4:*geo-area*,**Puglia**)	location(l_1,l_4)
onto(l_5:*geo-area*,**Sicilia**)	set(l_4,l_5)

Figure 2: The semantic interpretation of the sentence "Le temperature superano la media in Puglia e in Sicilia" given in terms of FoL predicates.

syntactic role of the dependents with respect to their head (the parent node). Consider the dependency tree n Fig. 1: *temperatura* (temperature) is the subject of the verb *superare* (exceed), while *media* (average) is the object; the coordinated words *Puglia* and *Sicilia* are modifiers of the verb.

The second step of the translation is the semantic interpretation: the syntax-semantics interface used in the interpretation is based on ontologies (Lesmo et al., 2011a; Nirenburg and Raskin, 2004). The knowledge in the ontology concerns the application domain, i.e. weather forecasts, as well as more general common knowledge about the world. Starting from the lexical semantics of the words in the sentence and on the basis of the dependency structure, a recursive function searches in the ontology providing a number of "connection paths" that represent the meaning of the sentence. Indeed, the final sentence meaning consists of a complex fragment of the ontology: semantic roles and other kind of semantic relations are contained in this fragment and could be extracted by translating it into First Order Logic (FoL) predicates. However, similar to other approaches (among others (Bunt et al., 2007)), our ontological meaning representation is unscoped. In Fig. 2 we report the semantic interpretation of the sentence "Le temperature superano la media in Puglia e in Sicilia" in terms of FoL predicates. The predicate onto expresses the lexical meaning of the words by using the ontology concepts: it assigns the concept instances exceed, temperature, average, Puglia, Sicilia to the FoL variables l1, l2, l3, l4, l5 respectively. Moreover, onto explicitly denotes the classes which these instances belong to: *meteo-status* is the ontological class of the events regarding the meteo; *geo-area* is the ontological class of the geographical areas; *eva-entity* is the ontological class of the evaluable entities. The predicates event, agent, theme, location express the semantics of the event in terms of predicate-arguments by using semantic roles (we adopt the set of semantic roles defined in the LIRICS project (Petukhova and Bunt, 2008)). Finally, the predicate set expresses a semantic relation that groups entities: this predicate allows to specify the cumulative reading, w.r.t. the distributive reading corresponding to have two not related locations.

2 A generator for LIS

Natural language generation can be described as a three steps process: text planning, sentence planning and realization (Reiterand and Dale, 2000). Text planning determines which messages to communicate and how to rhetorically structure these messages; sentence planning converts the text plan into a number of sentence plans; realization converts the sentence plans into the final sentences produced. Anyway, in the context of interlingua translation we simplify by assuming that generation needs only for the realization step. Our working hypothesis is that source and target sentences have as much as possible the same text and the same sentence plans. This hypothesis is reasonable in our projects since we are working on a very peculiar sub-language (weather forecasts) where the rhetorical structure is usually very simple.

In our architecture we use the OpenCCG realizer (White, 2006), an open source tool that has several appealing features with respect to our approach. OpenCCG is based on combinatory categorial grammars (CCG) (Steedman, 2000), a mildly contextsensitive formalism that is theoretically adequate to describe the complexity of natural language syntax (e.g. cross-serial dependencies, non-constituency coordination) and it has a very straight syntax-semantic interface. Moreover, OpenCCG adheres to the *bidirectional grammar* approach, i.e. there is one grammar for both realisation and parsing. It means that derivation and generation have the same structure and that we can develop a grammar by testing its correctness in realization in terms of parsing: as a result, we obtain a speed-up in the process of grammar development (White et al., 2010). Realization usually accounts for a standard number of morpho-syntactic phenomena, that are *inflection*, *agreement*, *word order*, *function words*. LIS has few function words but, similar to all SLs, it has a peculiar and rich system of inflection and agreement. OpenCCG allows to encode an inflectional system by using feature structures, which are part of the syntactic categories. The integration in one single elementary structure of the morphology-syntax-semantic information is appealing for sign languages where the absence of function words increases the importance of morpho-syntactic features to express the correct meaning of the sentence. Now we first give some specifications about the input/output of the generator (Section 2.1) and secondly we describe the treatment of some linguistic constructions by using a fragment of the CCG for LIS (Section 2.2).

2.1 Input and output

@l_1:*meteo-status* **exceed**	
@l_2:*eva-entity* **temperature**	@l_1 <agent> l_2
@l_3:*eva-entity* **average**	@l_1 <theme> l_3
@l_4:*geo-area* **Puglia**	@l_1 <location> l_4
@l_5:*geo-area* **Sicilia**	@l_4 <set> l_5

Figure 3: The semantic interpretation of the sentence "Le temperature superano la media in Puglia e in Sicilia" given in terms Hybrid logic predicates.

The input of the generator, that is the output of the semantic interpreter, are FoL predicates expressing a number of distinct semantic relations. Semantic situation type (e.g. event, state), semantic roles (e.g. agent, location), grouping relations (e.g. set, sequence), general semantic properties (as tense or plurality) can be produced by the semantic interpreter: we assume that at least semantic roles and grouping relations are explicitly expressed, as the interpretation in the Fig. 2. OpenCCG requires semantic interpretation in form of *hybrid logic* formulas, a kind of propositional modal logic that can be used to represent relational structures (Blackburn, 2000). Since hybrid logic is equivalent to a fragment of FOL, we could rewrite FoL predicates in terms of hybrid logic: (1) by identifying first order variables with *nominal* (a new sort of primitive logic elements which explicitly name the nodes of the relational structure); (2) by identifying first order predicate (of arity two) with *modality label* of hybrid logic (Brauner, 2008). Applying this algorithm to the FoL predicates in Fig. 2 we obtain the representation in Fig. 3.

Note that we assume a logical interpretation that does not adhere to the *linguistic meaning* notion that is usually adopted in OpenCCG, i.e. *Hybrid Logic Dependency Semantics* (HLDS) (Baldridge and Kruijff, 2002). HLDS defines semantic relations only between words, disallowing the definition of nominals that do not have a lexical predication (White, 2006). In contrast, our interpretation function produces a number of non-lexicalized structures for specific semantic constructions. One example is the interpretation of the ordinal numbers: the interpretation of "ultimo giorno del mese" (*last day of the month*) is $@X_0(\langle \mathsf{ODI} \rangle X_1 \wedge \langle \mathsf{ODRS} \rangle X_2 \wedge \langle \mathsf{ODS} \rangle X_3) \wedge @X_1 \textbf{day} \wedge @X_2 \textbf{month} \wedge @X_3 \textbf{last}$ (Lesmo et al., 2011b). In this hybrid formula, $\langle \mathsf{ODI} \rangle \langle \mathsf{ODRS} \rangle \langle \mathsf{ODS} \rangle$ are modalities which indicate specific semantic relations[2] and $X_0 X_1 X_2 X_3$ are nominals: in this specific case X_0 does not have a lexical predicate.

A challenging requirement of our project is related to the target language: LIS, as all signed languages, does not have a *natural* written form. As a consequence we developed an *artificial* written form for LIS in order to "communicate" the output of the generator to the virtual interpreter. This written form encodes the main morphological features of the signs as well as a number of non-manual fea-

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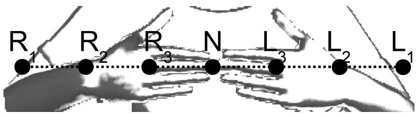
[2] $\langle$ODI$\rangle$ = Ordinal Description Iterator; $\langle$ODRS$\rangle$ = Ordinal Description Reference Sequence; $\langle$ODS$\rangle$ = Ordinal Description Selector.

Lexical Categories			
LEX	**PoS**	**SynCAT**	**SemCAT**
L_2_SUPERIORE_R_2	Verb	S [Y_0 ap=R_2] \ NP [Y_1 ap=R_2] \ NP [Y_2 ap=L_2]	@Y_0:*meteo-status* **(exceed** ^ <agent>Y_1:*eva-entity* ^ <theme>Y_2:*eva-entity*)
SICILIA_R_1	Noun	NP [X_0 ap=R_1]	@X_0:*geo-area* **Sicilia**
PUGLIA_R_3	Noun	NP [X_1 ap=R_3]	@X_1:*geo-area* **Puglia**
TEMPERATURA_R_2	Noun	NP [X_2 ap=R_2]	@X_2:*eva-entity* **temperature**
MEDIA_L_2	Noun	NP [X_3 ap=L_2]	@X_3:*eva-entity* **average**

Type Changing Rules				
SynCAT	**SemCAT**		**SynCAT**	**SemCAT**
NP [Y_0 ap]	@Y_0:*geo-area*	$\longrightarrow$	S [X_0] / S [X_0 ap]	@X_0:*meteo-status* <loc> Y_0:*geo-area*
NP [Y_0 ap=R_1]	@Y_0:*geo-area*	$\longrightarrow$	NP [X_0 ap=R_2] \ NP [X_0 ap=R_3]	@X_0:*geo-area* <set> Y_0:*geo-area*

Table 1: A fragment of the CCG for LIS: the articulatory position feature (**ap**) encodes the spatial location.

tures, as the gaze or the tilt of the head (Zhao et al., 2000). For sake of clarity we write a LIS sentence just as a sequence of *glosses*, that is the sequence of the names of the signs without representing any non-manual information. The only feature that we explicitly represent is the *spatial position* of the sign. In this paper we consider just the horizontal dimension in the signing space: we assume a discrete space of seven positions L_1 (the leftmost position), L_2, L_3, N (the neutral position), R_3, R_2, R_1 (the rightmost position).



For signs that have just one articulatory position, we use the prefix L_i (R_j) in the gloss to indicate that a sign is performed on the left (and on the right) of the signer. For signs that have two articulatory positions (starting and ending position), we use the prefix L_i (R_j) in the gloss to indicate that a sign starts on the left (on the right) of the signer and the suffix L_l (R_m) in the gloss to indicate that a sign is performed on the left (and on the right) of the signer.[3]

2.2 A CCG for LIS

In Tab. 1 we present the fragment of the hand-written CCG: the grammar is organized in *Lexical Categories* and Type-changing rules. Each Lexical Category has four fields: **LEX**, that contains the lexical form of the item; **PoS**, that contains the part of speech category; **SynCAT**, that contains the syntactic category; **SemCAT**, that contains the semantic category. Note that SynCAT e SemCAT are related by using *semantic variables* (X_i and Y_j in Tab. 1): these variables appear in the syntactic categories, but are used as pointers to the semantic categories (Baldridge and Kruijff, 2002; White, 2006). Some Lexical Categories which have specific SynCAT-SemCAT values can change these values by using the type-changing rules.

The CCG accounts for two specific morphosyntactic phenomena: (i) spatial agreement between verb and its arguments and (ii) NP-coordination. Similar to American SL in LIS we can tell a number of verb classes on the basis of spatial accord (Volterra, 2004; Wright, 2008). For instance the verb L_i_SUPERIORE_R_j (*exceed*) belongs to the class II-A, i.e. it is a transitive verb such that the

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[3] As it is customary in the sign languages literature, we use names in uppercase for the signs that are related to their rough translation into another language, Italian in our work.

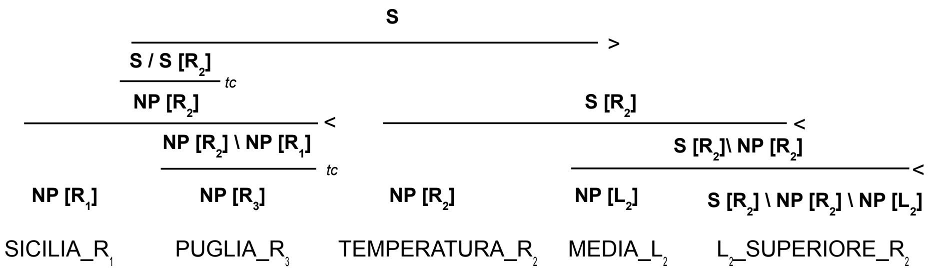

Figure 4: The realization/derivation of the LIS sentence "SICILIA_R_1 PUGLIA_R_3 TEMPERATURA_R_2 MEDIA_L_2 L_2_SUPERIORE_R_2" (for space reasons we do not show the semantics of the derivation).

starting position of the sign (L_i) coincides with the position of the agent, as well as the ending position of the sign (R_j) coincides with the position of the theme (or patient) (Volterra, 2004). Similar to (Wright, 2008), we model this feature in CCG by using a morphological feature called ap (articulatory position). The ap feature encodes the position of the noun in the atomic category NP, as well as the starting and ending position of a verb in the complex category $S\backslash NP\backslash NP$. NP coordination in LIS is realized in two distinct ways, i.e. (1.) by signing the NP in one single position but separating them by a *pause* and (2.) by signing the first NP into a particular position and signing the second NP in a distinct but related position: in our grammar we developed only the second option. Our CCG analysis of NP-coordination uses unary type-change operation and, in contrast to (Wright, 2008), does not assume a specific lexical unit that expresses coordination: Wright models the hand movement as a lexical unit (the "shift") that contains the category $NP\backslash NP/NP$. In contrast, we give a lexical value to the feature ap: similar to the CCG analysis of case-based language (e.g. Japanese, (Steedman, 2000)), we consider the position as a specific case. In particular, we suppose that the type-change operation is possible just with some specific ap values, obtaining a complex category for the second NP in the coordination.

In Fig. 4 we report the realization (coinciding with the derivation) of the LIS sentence "SICILIA_R_1 PUGLIA_R_3 TEMPERATURA_R_2 MEDIA_L_2 L_2_SUPERIORE_R_2" based on the lexicon in Tab. 1, that is the LIS translation of the Italian sentence "Le temperature superano la media in Puglia e in Sicilia". In accord to (Geraci, 2004) and in contrast with (Volterra, 2004) we assume that LIS respects the SOV order. In the generation, the unification mechanism on the feature *ap* constraints the NP arguments to accord with the starting and ending position of the verb: the agent TEMPERATURA is signed in the position R_2, that corresponds to the starting position of the verb SUPERIORE, while the theme MEDIA is signed in the position L_2, that correspond to the ending position of the verb. This mechanism avoids the generation of ungrammatical derivations as "TEMPERATURA_R_1 MEDIA_L_2 L_2_SUPERIORE_R_2", in which the positions of TEMPERATURA and SUPERIORE do not agree. Finally note that in the generation we have two type-change operations. The first one is used to account for NP coordination, as explained above. The second type-change is used to transform the NP into the complex sentence modification category S/S, since LIS does not have prepositions. Note that in order to limit over-generation we constrain both type-changes by using the semantics of the lexical category by requiring that the semantic ontological type of the lexical category is a *geo-area*, i.e. a geographic area.

3 Conclusion and ongoing work

In this paper we presented the main features of a generator for LIS. The generator is based on the OpenCCG tool and relies on a hand encoded CCG grammar to account for a number of peculiar linguistic phenomena of Sign Languages. Many improvements are necessary in order to encode further syntactic phenomena and to take account for a realistic large lexicon. In our opinion a crucial point is the encoding of topic-comment relations, that seem to have an important role in the word order of the LIS sentence.

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