Processing linguistic data for GSL structure representation

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Abstract

The here presented work reports on incorporation of a core grammar of Greek Sign Language (GSL) into a Greek to GSL conversion tool. The output of conversion feeds a signing avatar, enabling dynamic sign synthesis. Efficient conversion is of significant importance in order to support access to e-content by the Greek deaf community, given that the conversion tool may well be integrated into various applications, which require linguistic knowledge. The converter is built upon standard principles of Machine Translation (MT) and matches Greek parsed input to equivalent GSL output. The transfer module makes use of NLP techniques to enrich linear sign concatenation with GSL-specific complex features uttered both manually and non-manually. GSL features are either checked against properties coded in a lexicon DB for base signs or they are generated by grammar rules. The GSL computational grammar is based on natural data analysis in order to capture the generative characteristics of the language. The conversion grammar of the transfer module, however, makes use of a number of heuristic solutions. This is implicated by the type of input for conversion, which derives from a statistical shallow parser, so that various semantic features have to be retrieved by mere grouping of lemmata. However, this type of input is directly connected with the requirement for fast processing of vast amounts of linguistic information.

1. Introduction

GSL sign synthesis originally involved dynamic generation of single signs (word level linguistic units). In this framework, a library of sign notation features has been converted to motion parameters of a signing avatar (Karpouzis et al., 2005). These features, allow to represent the "phonological structure" of any sign and along with a set of GSL specific features relevant for sign formation, accompany sign lemmata in a multipurpose lexicon data base (Efthimiou et al., 2004). Exploitation of sign synthesis to access e-content, required to extend synthesis to phrase level. A computational grammar based on Unification Grammar principles (Shieber, 1992) is developed to provide for generation of GSL structures.

For the representation of the phonological features of GSL the extended HamNoSys annotation system (Prillwitz et al., 1989; Hanke, 2002) has been adopted. Sign coding is further enriched to provide for the non-manual obligatory features, which accompany hand action in order to make linguistic content fully acceptable. Mouthing patterns, facial expressions and body/shoulder movement -also used for the indication of phonetically (stress) or syntactically uttered (focus position in sentence) elements of the linguistic message in spoken languages- comprise the multi-layer information coded in the GSL lexicon DB. Eyebrows movement and eye gaze are also coded, when present, since they are significant obligatory parts of GSL sign formation.

The computational grammar GSL can handle sign phrase generation as regards the basic predicate categories and their complements, and extended nominal formations. The rules generate surface structures with a linear ordering that corresponds to basic sign sequences in a phrase. Maximal phrase feature bundles (Carpenter, 1992) contain features for both linear and non-linear linguistic information.

Here, we report on how these resources are exploited in the environment of a conversion tool that matches structured chunks of written Greek to GSL structures. Emphasis is put on structure matching between the two languages, and coverage of grammar phenomena of GSL.

2. Greek to GSL converter description

The converter (Fotinea et al., 2005) is programmed in Java to allow for quick and efficient design development compatible with all system platforms. XML technology has been utilized as a means for describing structured documents in a re-usable format, while Java technology contains embedded tools for the management of XML texts. Hence, the converter utilizes multi-level XML-based annotated sentences, exploiting XML technologies for its collaboration with the shallow parsing sub-module that creates the Greek parsed chunk input for conversion.

The conversion tool performs top-down, rule-based meta-syntactic analysis. Rules are organized in three sets, the structure set, the chunk set and the feature set. The structure set allows for linguistic actions involving (conditional) re-ordering of chunk sequences to reflect the morpheme order of GSL. A second set of rules performs on the chunk level, allowing for addition, deletion or modification of specific entries, whereas a third set of rules applies to feature level, to perform either insertion of mostly GSL specific features, or modification or deletion of existing features, if required for GSL synthesis. Provision has been made that the user may arrange rules into user-defined rule sets, allowing for execution/testing of either all rules or any given combination. Rule execution is iterative and for each iteration all rules are examined, the output of each rule serving as the input of the next, provided that the rule context ('if-part') is satisfied. Iterative execution continues as long as change of the input occurs. In Figure 1, a screen shot of the application environment is depicted. The upper half of the screen shows chunked input and the bottom half depicts the output (single rule execution example).

3. GSL grammar coverage

The computational grammar currently handles analysis and generation of both clause- and phrase-level phenomena of GSL, which demand both linear and multi-layer handling. Structures are enriched with GSL-specific features related to the various phenomena of the language.

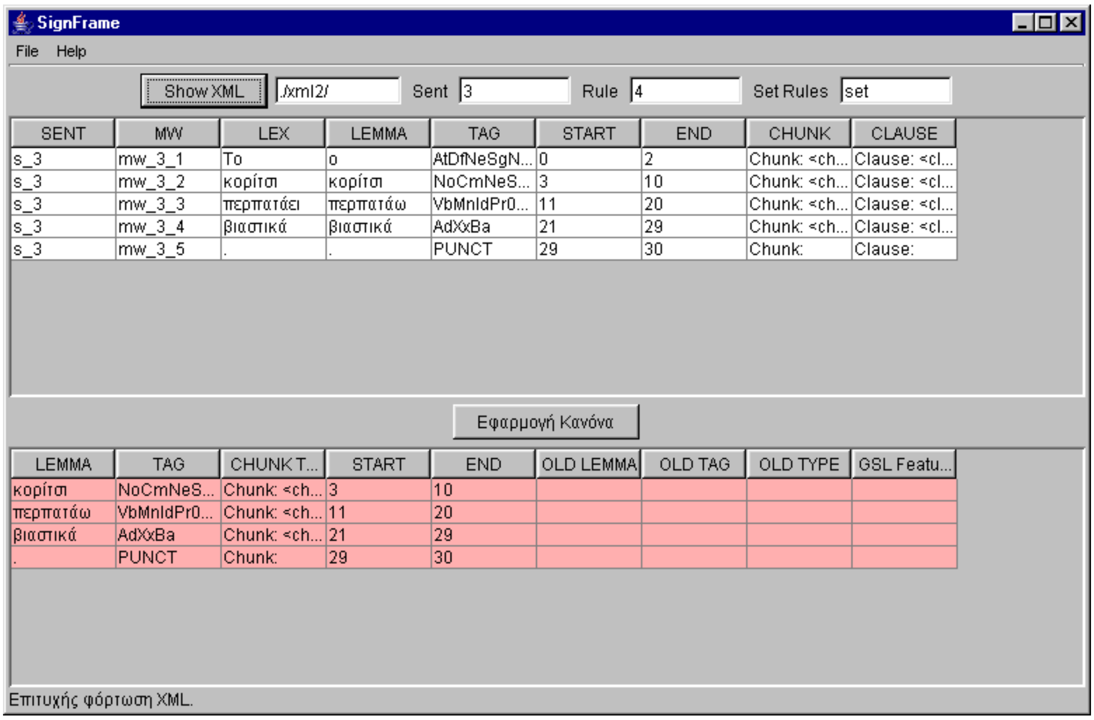

Figure 1: The application environment of the conversion tool.

A subset of these features is coded as lemma-related properties in the GSL lexicon database, and they acquire specific values in rule descriptions after search in the lexicon. A typical example is plural formation where NP plural value resulting from agreement checking inside NP, receives the GSL-specific feature for plural morphology that is coded to the lemma of the base sign (head of the construction). This type of morphological enrichment is required in order to allow for correct representation of the analysed phrase by an avatar in a computational environment (see also on the same subject Marshall & Safar (2005)), but also reflects the morpho-syntactic rule of the grammar a human signer utilizes when uttering the specific phrase.

The lexicon that interacts with the computational grammar codes both articulatory and morpho-syntactic features of lemmata. Figure 2 depicts part of the fields of grammar information coded in the lexicon database, where 2(a) shows the manual and non-manual obligatory features for sign articulation, and 2(b) depicts indicative morpho-syntactic features related to lemma entries.

As regards lemma formation (Figure 2(a)), the 'yes' value in the field for eye gaze as well as the different mouthing values display obligatory simultaneous performance with HamNoSys annotated hand motion. For example, plural 'YOU' (id 26) as coded in the lexical DB, demands obligatory eye gaze performance (towards the addressee).

Morpho-phonological properties of GSL, as for example plural properties (Figure 2(b)) are coded in the field 'np_plural', the different values of which correspond to plural formation with numeric value or quantifier on singular sign (i.e. '2, 3, … days', '2, 3, … pencils' etc), to formation with movement repetition and/or change in space (i.e. as in the case of 'book', 'tree' and 'child') and to 2handed formation, if the singular sign is formed with one hand and not body anchored (i.e. 'airplane').

The semantic values related to the field 'GSL_aspect' provide information on language intrinsic adverbial properties for the definition of continuation, duration, degrading, intensity or repetition related to the action indicated by the predicate. 'GSL_aspect' value 'dur' indicates that the sign movement continues for longer than default, 'dim' signifies small span of movement to indicate minimal action/event (i.e. with predicative base signs such as 'wind-is-blowing', 'I-walk', 'I-speak', 'I-eat' etc), 'int' denotes bigger span and abrupt pauses in movement (i.e. with signs as 'feel-a-pain', 'it-rains' etc) and 'rep' indicates obligatory repetition of sign movement with interval pauses (i.e. with signs as 'ask' or 'travel').

A number of parameters related to traditional linguistic analysis have been taken into account, in order to decide on the structures to be adopted as the default output of analysis. As regards predicate classification, empirical evidence and related analysis (Sapountzaki, 2005) support three main clusters 'Simple Predicates', 'Predicates of Direction' (i.e. predicate 'give') and 'Spatial Predicates' (predicates of movement in real space, i.e. 'walk'). The current grammar implements a pattern which incorporated both simple and spatial predicate formations. Predicates of direction are not yet treated, since they heavily involve use of classifiers that are not yet implemented in the conversion grammar.

As regards word order options, two orders for clause-formation appear to be acceptable in a wide range of data related to the predicate categories under consideration. The one involves strings of the type [Agent-Predicate-Complement], whereas the other arranges constituents in [Agent-Complement-Predicate] strings.

Id	Lemma	HamNoSys	Mouthing	Eye gaze
4	ΤΡΕΧΩ	[illegible]	OL7	
13	ΜΑΛΩΝΩ	[illegible]	CN17	
5	ΚΑΤΗΓΟΡΩ	[illegible]	CN17	
3	ΦΙΛΩ	[illegible]	CN14	
26	ΕΣΕΙΣ	[illegible]		YES

(a) Manual and non-manual obligatory features for sign articulation.

Id	Lemma	Word family	GSL aspect	Np plural	Can be a topic	Noun verb modification	Syntactic movement	Real movement	Becomes classifier	Combines with classifier
13	ΜΑΛΩΝΩ	επιθυμία φωνάζω			No	No	No	No		No
5	ΚΑΤΗΓΟΡΩ	επικίνδυνος			No	No	No	No		No
2	ΕΒΔΟΜΑΔΑ		Rep	1	Yes					
31	ΑΓΑΠΩ	αισθήματα	Dim/Int		No	Yes	No	No		No
7	ΑΓΟΡΙ		Dim/Int	1	Yes					Yes

(b) Grammar features related to lemma entries.

Figure 2: Fields of grammar information coded in the lexicon database.

For reasons of computational efficiency, implementation has adopted the [Agent-Complement-Predicate] arrangement, given that the specific order is supported by theoretical analysis (Efthimiou, 2006) as the basic word order of the language and also allows for an adequate handling of the set of phenomena that take place on clause level (sentential negation, tense declaration, interrogation, etc). Adoption of this order also facilitates handling emphasis assigned to either predicate arguments or various sentential adjuncts (i.e. temporal adverbs).

Surface deviations of the acknowledged concatenation order as regards main constituents of the clause are treated as cases of emphatic structures. Our approach provides for a clause-initial position undefined for grammatical category, which serves as a place-holder for emphasis, similar to an analysis proposed for the Greek language (Efthimiou & Zombolou, 1995). In the cases where this position is filled, the surface linguistic data seem to deviate from the standard constituent concatenation patterns of the language.

This however, is not true, if we adopt the structure pattern for clause formation: [Emphasis_Position-Agent-Complement-Predicate]. When no emphasized constituent is present, the clause-initial position remains void. Otherwise, any constituent may fill the clause-initial position, receiving accordingly the interpretation of emphasis. In this sense, the Emphasis_Position is free for any semantic category, including the Agent, the Patient, the Beneficiary as well as all types of phrases with adverbial value (locative, temporal, etc).

Various operations inside the NP, mainly involve constituent arrangement around the head, including actions of deletion of information irrelevant to articulation in 3D space (i.e. determiner deletion), and feature insertion obligatory for the reconstruction of information articulated in a multi-layer manner in GSL (i.e. mouthing patterns parallel to head sign formation for quantitative adjectives). Special provision is made that when the head of the input NP is characterized as proper, instead of searching the bilingual lexicon, a finger spelling procedure is activated for the representation of the string of characters forming the proper name.

A detailed description of the phenomena that currently comprise the GSL computational grammar follows, along with a discussion on handling the matching parameters implemented for the needs of the conversion operation.

4. Rule description

4.1. Clause level operations

4.1.1. Sentence word order

As already stated the default clause formation order takes into account concatenation instantiations of one- and two-place predicates along with options for various sentential adjuncts. Whereas for main clause constituent arrangement, the predicate systematically fills the string-final position, in the case of two-place predicates the Agent always precedes the predicate Complement, resulting in strings as in the examples below (Ex.1-2).

(Ex.1) BOY COME
= A boy comes

(Ex.2) I TEACHER LIKE
= I like the teacher

Temporal phrases are placed in clause-initial position, reserved for emphasized constituents (Ex.3).

(Ex.3) FRIDAY I CHURCH GO
= On Friday I go to the church

However, Greek temporal adverbs such as 'χθες (=yesterday)', 'αύριο (=tomorrow)', 'σήμερα (=today)' are treated by special lexical rules that obligatorily delete the Greek lemma and incorporate the temporal value of the adverb as a complex eye-gaze and head-movement feature on the GSL predicate. An example, shown next (Ex.4), presents the output of the conversion operation after having applied clause structuring, deletion of input lemma and feature insertion for multi-layer representation.

(Ex.4) I CHURCH GO + EYE_GAZE + HEAD_MOVEMENT(RECENT_PAST)
= *Yesterday I went to the church*

The conversion operation related to Ex.4 is sketched in Figure 3, where the left-hand part indicates written Greek chunked input and the right-hand part the resulting GSL structure. The GSL recent past feature ('GSL_Rec_Pa') on the predicate lemma indicates activation of obligatory eye gaze and related head movement.

4.1.2. Sentential negation

Sentential negation is treated as required by the adopted clause concatenation order, that is, in the output of the conversion operation a negative particle is always adjuncted to the clausal predicate as discussed in Section 4.2 (Verb Group operations). As regards theoretical analysis see also Antzakas & Woll (2002).

4.1.3. Existential verb deletion

GSL does not make use of existential predicates, like 'be'. In order to convert Greek sentences into GSL the existential verb has to be deleted and a pause has to be inserted between Agent and Attribute, where the tense indication (except present tense) has to be transferred to the output and be represented with a temporal sign. For the example below (Ex.5), the converter rule for existential verb deletion is given in Figure 4.

(Ex.5) YANNIS+FING_SPELL+PAUSE DOCTOR
= *John is a doctor*

4.1.4. Deictic subject doubling

If the input string contains a pronominal element characterized as 'strong' in the Greek analysis notation (opposite to 'weak' that corresponds to clitic pronouns of Greek), the right-hand side object has to contain the GSL equivalent to the full personal pronoun, which in this case is the deictic pronoun. Deictic Agent, if present, has to be repeated at the end of the utterance (mainly for verification of Agent information in the case of lengthy utterances). An example is given in Figure 5, which results in strings as in examples (Ex.6-Ex.7).

(Ex.6) HE+DEICTIC COME HE +DEICTIC
= *He comes*

(Ex.7) I+DEICTIC BOOK WANT I+DEICTIC
= *I want the book*

4.2. Verb Group operations

The predicates currently treated in the grammar, present a number of characteristics (Fischer, 1996) which differentiate them from the predicates of direction. In the clause output, the arguments of simple predicates are uttered as separate signs, following the concatenation order(s) of the language. As concerns the predicate articulation, location and direction of movement remain constant, whereas sentential negation, when present, is realized with the utterance of a negative particle strictly following predicate articulation (Ex.7-8).

(Ex.7) I TEACHER THIS LIKE
= *I like this teacher*

(Ex.8) ________ neg
I TEACHER THIS, LIKE NOT
= *I don't like this teacher*

An exception to general negation rule present predicates which allow for the expression of negation by morphological means inside the base sign. In this case, negation of the semantic content of the predicate is realized by applying mirror image movement (reverse movement) as to start position, i.e. in the case of negation of the predicate 'want' (Ex.9). For such predicates it is necessary to treat sentential negation by a lexical rule that matches the input lemma plus negation features, with a separate sign lemma.

(Ex.9) _______ neg
I BALL THIS NOT-WANT
= *I don't want this ball*

A feature insertion operation involves incorporation of adverbial semantic values in the predicate morphology. To treat elements as i.e. 'much', 'a little', 'continuously' -expressed in GSL on predicate morphology- the current implementation, activates list searching of adverb - predicate cluster combinations in the input string, in order to assign a specific value to the predicate feature 'GSL_aspect'. Indicative examples are presented next (Ex.10-11).

(Ex.10) I EAT+GSL_ASPECT=dur I
= *I eat a lot*

(Ex.11) RAIN+GSL_ASPECT=int
= *It rains heavily*

4.3. Noun Phrase operations

NP formation in GSL typically lacks open determiner declaration where a number of specifiers, such as qualitative adjectives, are incorporated in base sign articulation as extra (mouthing) features. The lexicon codes base sign articulation as to manual and non-manual obligatory parameters. Any context-dependent information on the base sign has to be reconstructed by rule-based feature insertion.

4.3.1. Article deletion

If the analysis of Greek input string has recognized the existence of a determiner inside NP, then a deletion operation is performed. In the examples 2 and 3 (Ex.2-3) above, one can see the result of this operation.

4.3.2. Adjective absorption

Adjectives are either listed in a concatenation of separate signs, adjuncting properties on the head sign, or they convey their semantic properties, by being uttered simultaneously with the head sign as additional multi-layer features.

In the latter case, they are uttered as a (combination of) facial expressions, simultaneously performed with base sign articulation. A typical instantiation of the above involves expression of qualitative adjective values like 'nice/good/ugly' etc. These values correspond to different mouth patterns in GSL. To resolve this type of conversion problem from Greek, a similar approach has been adopted as the one applied for addition of adverbial values to predicates. In this case, the list of lemmata to be translated to features includes the clusters of different adjectives.

Example (Ex.12) illustrates the multi-layer structured NP "nice apple", being the output of application of the relevant lexical rule, for the case of qualitative adjectives.

(Ex.12) APPLE+MP_CN17
= *nice apple*

```
(SENT   <S>
        SYN     [cl
        SYN     [advp
        TOK     χθες      χθες      AdXx     ad_temp
        SYN     /advp]
        SYN     [np_nm
        SYN     *sing
        TOK     Ένας      ένας      AtIdMaSgNm
                atidsgnm
        TOK     άνθρωπος            άνθρωπος
                NoCmMaSgNm  nosgnm
        SYN     *sing
        SYN     /np_nm]
        SYN     [vg
        SYN     *sing
        TOK     έφαγε    τρώγω
        VbMnIdPa03SgXxIpAvXx            vb_sg
        SYN     *sing
        SYN     /vg]
        SYN     [np_ac
        TOK     τα        ο         AtDfNePlAc
                atdfplac
        TOK     μήλα      μήλο      NoCmNePlAc
                noplac
        SYN     /np_ac]
        SYN     /cl]
        PTERM_P           .         .
        PTERM_P                     punct_fs
        )SENT   </S>
```

```
(SENT   <S>
        SYN     [cl
        SYN     [Agent
        SYN     *sing
        LEM     άνθρωπος
        SYN     *sing
        SYN     /Agent]
        SYN     [Compl
        SYN     *plural
        LEM     μήλο     GSL_Pl01
        SYN     *plural
        SYN     /Compl]
        SYN     [Pred
        SYN     *sing
        LEM     τρώγω
        Id03Sg+GSL_Rec_Pa
        SYN     *sing
        SYN     /Pred]
        SYN     /cl]
      )SENT   </S>
```

Figure 3: Multi-layer indication of recent past in GSL.

```
RULE                                    % Existential verb deletion rule
If Clause=*
       [np_nm][vb_eimai_id][np_nm]
      *
THEN Clause=*                           % delete existential verb
      [np_Agent]= [np_nm]
      [np_Attribute]= [np_nm]
      GSL_Tense=Read_Tense_from_Predicate_Attributes(vb_eimai_id);
      *
```

Figure 4: Existential verb deletion rule.

```
RULE                                    % Deictic pronoun subject doubling when pronoun is present
If Clause=*
       [np_nm and "Pn*St"] % Εγώ, εσύ, αυτός... Pronoun*strong
       [vg] % verb group
      *
THEN Clause= *
          [np_Agent_Deictic]=  [np_nm]
           *
          [vg]
          [np_Agent_Deictic]               % deictic pronoun subject doubling
```

Figure 5: Deictic pronoun subject doubling when pronoun is present.

4.3.3. Adjective concatenation

In general, adjectives, which are not represented by a bound morpheme, as described in the above sub-section,, are adjuncted to the right of the head sign. This structure pattern is retained in the current grammar implementation. During conversion, if an adjective phrase is present, np processing also involves a swap operation, the result of which is post-head positioning of adjective(s), while preserving input adjective phrase order of appearance. The output of swap operation is exhibited in example (Ex.13).

(Ex.13) KITCHEN LARGE BRIGHT
= *large, bright kitchen*

5. Future Research

The converter in its current implementation receives input from a shallow statistical parser for Greek which provides rough structural descriptions which do not carry extensive semantic information. The leaves of the so created structures contain feature descriptions which derive from a morphology based lexicon. In order to match input strings to adequate GSL structural representations, there has been used list matching according to semantic properties that are not directly visible in the source chunks, but, in this way, they are properly generated in the target structures. However, many GSL dependant issues remain untouched. The next research target involves searching for solutions as regards integration of classifier use in structure formation. An example is provided by the various GIVE formations that incorporate the classifier for the object. The natural signer incorporates the classifier indicating the semantic class of the object into the movement for GIVE formation, a procedure that creates a number of different entries in the lexicon, all recognized as various actions of giving.

sign: GIVE-MONEY / flat (perceived as-) 2D object
sign: GIVE-ROUND-OBJECT / 3D object
sign: GIVE-PENCIL / thin (perceived as-) 2D object
sign: GIVE-BOOK / flat (perceived as-) 3D object

6. Conclusion

The computational grammar exploited by the converter certainly covers a limited number of phenomena, and also reveals many of the issues still requiring an adequate handling in respect to their implementation, in order to achieve fully annotated strings as to information carried by natural signing utterances. However, its architecture allows extensibility with respect to further rule coding, at low computational cost.

The implemented subset of grammar rules are derived from an extensive formal grammar of GSL that captures the generative properties of the language. This grammar is the product of theoretical linguistic analysis of natural language data, and provides its first formal description, covering all levels of representation (phonology, syntax and semantics).

At the current stage, implementation has disclosed the potential of adequately coding signing linguistic information to an extent that allows recognition of the produced utterance as part of the language.

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