Modeling Information-Passing within the LFG-Workbench

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Introduction

If NLP applications want to deal with "real life texts", it is certainly also necessary to consider the processing of linguistic units, which are larger than sentences. And as it is well known, the structure and the interpretation of sentences embedded in larger units is often distinct from the structure of sentences, which are standing alone. The resolution of cross-sentential anaphora is one of the problems we have to deal with, when we switch towards the analysis (or synthesis) of such larger linguistic units. In order to have a correct treatment of the cross-sentential anaphora, one has to be able to refer back to an antecedent, which is to be found in a preceding sentence: some information about a possible antecedent must be stored in order to be *passed on* to following sentences and to allow the anaphoric link, if some of the subsequent sentences are containing an anaphora. Using this concept of *information-passing* and the unification technique, a resolution of the pronoun can then be tried out: parts of the semantic information of the pronoun are going to be compared (unified) with specific parts of the semantic information of the (possible) antecedent.

I implemented this within two NLP platforms: the LFG Grammar Writer's Workbench and the ALEP platform[1], both of them conceived for the development of grammars based on unification formalisms.

In the next section I will present the semantic framework I based my work on and which introduces the idea of "information-passing" in order to cope with cross-sentential anaphora: the Dynamic Predicate Logic (DPL). DPL also proposes solutions for the treatment of so-called 'donkey sentences'. In the following section I will very briefly show how a very first implementation of this framework can be modeled within the LFG Workbench. I focused on the possible machine translation of cross-sentential anaphora.

1 DPL as Representation Language for Information-Passing

The Dynamic Predicate Logic (DPL) results from an investigation in the dynamic semantic interpretation of the language of first order predicate logic and is "intended as a first step toward a compositional, non-representational theory of discourse semantics"[2]. This approach is concerned among other things with the cross-sentential anaphora. The dynamic aspect

[1] See [Declerck 1996].
[2] I am refering here to [Groenendijk 1991].

resides in the fact that, for this framework, the meaning of a sentence doesn't lie in its truth conditions, but "rather in the way it changes the ... information of the interpreter"[3]. DPL considers only the information change which concerns "their potential to 'pass-on' possible antecedents for subsequent anaphors"[4]. The Dynamic Predicate Logic is based on the syntax of the standard predicate logic, but proposes a new (dynamic) interpretation of the quantifiers and connectives which allows the binding of variables within and outside their scope, depending on the interpretation of the corresponding expressions of the natural language.

Two (strong) assumptions, which are controversial in the discussion on this topic, are underlying the DPL approach: Indefinite NPs are considered to be *quantificational expressions* and pronouns to act like *variables*. Not everyone agrees on those assumptions, as this can be seen in the Discourse Representation Theory or in the work by Irene Heim[5]. But those assumptions are here important if one wants to provide a uniform translation of indefinite NPs into existential quantifier (see below). And the desired compositional treatment requires that the information concerning the pronouns is to be found in the sentences uttered so far, i.e. as included within the scope of a logical quantifier or connective.

The particular expressions of the natural language DPL is dealing with are the following:

(1) A man walks in the park. He whistles. – cross-sentential anaphora
(2) If a farmer owns a donkey, he beats it. – donkey sentence
(3) Every farmer who owns a donkey, beats it. – donkey sentence

And the problem consists in providing an adequate semantic representation of the anaphoric links. There are several ways of representing the semantic interpretation of each of the utterances and three of them (1 - 3) are discussed by Groenendijk & Stokhof:

(A) In classical predicate logic:

- $\exists x[man(x) \wedge walk\_in\_the\_park(x) \wedge whistle(x)]$ (1)
- $\forall x \forall y[[farmer(x) \wedge donkey(y) \wedge own(x, y)] \rightarrow beat(x, y)]$ (2) & (3)

(B) In a compositional way:

- $\exists x[man(x) \wedge walk\_in\_the\_park(x)] \wedge whistle(x)$ (1)
- $\exists x[farmer(x) \wedge \exists y[donkey(y) \wedge own(x, y)]] \rightarrow beat(x, y)$ (2)
- $\forall x[[farmer(x) \wedge \exists y[donkey(y) \wedge own(x, y)]] \rightarrow beat(x, y)]$ (3)

(C) In the Discourse Representation Theory:

- $[x][man(x), walk\_in\_the\_park(x), whistle(x)]$ (1)
- $[][[x, y][farmer(x), donkey(y), own(x, y)] \rightarrow [][beat(x, y)]]$ (2) & (3)

What is missing in (A) is the compositional representation of the subparts of the utterances. Another disturbing point is the distinct translation of the indefinite NPs into the representational language, once as an existential quantifier (A,1) and once as an universal quantifier

[3] Ibid. p. 43
[4] Ibid. p. 44
[5] See [Kamp 1981] and [Heim 1982, p. 122]

(A,2 & A,3). The fact that (A,2) and (A,3) translate into the same semantic representation is also reflecting the non-compositionality of the classical predicate logic.

The problems with the compositional representation (B) are concerning the binding of the variables (the pronouns in the natural language). In (B,1) the third occurence of the variable x is free and thus doesn't allow the anaphoric reading. The same remarks are valid for x and y in (B,2) and for y in (B,3). But the way (B) is representating the utterances allows the uniform translation of indefinite NPs into an *existential quantifier*.

The problems with the DRT representation are more of methodological nature, since on the treatment of those cases DPL and DRT are empirically equivalent. In short: Groenendijk and Stokhof are missing the compositional building of the semantic representation and also would prefer to use a more classical representational language, like the one of first order logic. For this, they are 'merging' together the representation (A) and (B), and considering now only the first case (1), the dynamic semantic interpretation is going to be like (B,1):

$\exists x[man(x) \wedge walk\_in\_the\_park(x)] \wedge whistle(x)$,

but with the existential quantifier having scope over the conjunction of the two sentences, this representation is going to be equivalent to:

$\exists x[man(x) \wedge walk\_in\_the\_park(x) \wedge whistle(x)]$.

This is possible because the interpretation of a sentence doesn't lie in a set of assignements, but rather in a set of ordered pairs of assignements, where those pairs represent the *input-output* states of a sentence. In our example, the first sentence has an output which is as the same time the input of the second one. Since the existential quantifier is interpreted as being able to quantify outside its scope (also in combination with the *conjunction* and the sequencing of sentences), the information concerning the (possible) antecedent is going to be passed-on to following sentences, which could be subsequently uttered. The fact that the existential quantifier in DPL is interpreted as a quantifier which can bind outside of its syntactic scope allows to say that we provide a compositional treatment of the utterance, the second sentence being interpreted as it comes, without referring to some metalinguistical representation or process. The existential quantifier is qualified as an *externally dynamic quantifier*.

Not every quantifier (or connective) has the dynamic property of binding outside of its scope; the universal quantifier, for example, can bind within its scope, but not outside of it:

(4) *Every man walks in the park. He whistles

is ruled out. The dynamic semantic interpretation of this quantifier blocks the passing of the information: the ouptut of the first sentence is empty (with respect to the information concerning anaphoric binding). The input of the following sentence will therefore contain no information allowing a resolution of the pronoun.

The way DPL is interpretating the distinct quantifiers and connectives is the following one:

- Existential quantification and conjunction are *externally* dynamic.
  They can bind variables within and outside their scope:

  [A man]$_i$ walks in the park and he$_i$ whistles. He$_i$ is happy

- Universal quantification and implication are *internally* dynamic.
  They can bind variables only inside their scope:

  Every farmer who owns [a donkey]$_i$, beats it$_i$
  *[Every man]$_i$ walks in the park. He$_i$ whistles
  If [a farmer]$_i$ owns [a donkey]$_j$, he$_i$ hates it$_j$
  *If [a farmer]$_i$ owns [a donkey]$_j$, he beats it. He$_i$ hates it$_j$

- Negation and disjunction are *static.*
  They cannot bind variables (at least, they don't allow a anaphoric reading):

  *[No man]$_i$ walks in the park. He$_i$ whistles
  *[A man]$_i$ walks in the park or he$_i$ whistles

This may appear too simple and indeed for some english examples it seems to be wrong. The authors are considering and discussing the cases which contradict the assumptions and give some hints in order to integrate those cases. I will not discuss this point here, but just mention, that for the German grammar, we are developing, we should have a look at a detailled analysis of the meaning of such expressions[6]. Once this has been done, we can encode this information in the lexicon (as will be seen in one of the the next sections). But here we can say that the DPL approach allows us, to a certain degree, to account for the resolution of anaphora without having to leave the field of linguistic descriptions. With the only means of the grammar and the formalism we have, we are able to provide a first and simple description of those phenomena. It is still to be investigated how sophisticated such a treatment can be.

2 A first Implementation of the Dynamic Interpretation within the LFG Workbench

In this case, my work consisted in the extension of a German Grammar written at the IMS (University of Stuttgart)[7]. The resolution of cross-sentential anaphora (but also the treatment of 'donkey sentences') has been achieved on a extra level of representation, the *d*-structure (= discourse level)[8], which is based on a traditional predicate-argument-based semantic representation (the *s*-structure). Then a translation module has been written, the transfer being described only on the discourse structure. So it was possible to translate the german text 'Der Bauer kauft [einen Wagen]$_{NPmasc-sing}$. Der$_{masc-sing}$ ist teuer' into the (correct) french text: 'Le paysan achète [une voiture]$_{NPfem-sing}$. Elle$_{fem-sing}$ est chère'.

In the following subsections, I will mainly concentrate on some commentaries on the GWB output of the simple discourse: "Ein Mann pfeift. Er geht." (A man whistles. He walks.). The reader should apologize the fact, that I never found time to describe the grammar in a

[6] As for example in [Bethke 1990] or in [Vater 1979].
[7] See [Berman 1995]
[8] See [Kaplan 1989]. Originally I called this level of representation the *a*-structure, but I discovered that this naming had already been used for the description of argument structures. The grammar fragment presented bellow has still not been adapted and some descriptions still occur on the a-structure.

more elegant way. Since I've been working in other projects, it was not possible to achieve the work. The state of the art is more the one of an experimental action.

2.1 The Lexicon

Three entries are here showed. Since they are described within templates, it is difficult to see how they participate to the building of structures. But this will become clear, once one looks at the output of distinct projections bellow. The names of templates beginning with "ALPHA" should be read now as "DELTA". There was no time to change the naming of the items.

```
  ein     D * @(PRED_DET INDEF)
              @NOM_OR_AKK
              @SG
              { @NEU
               |@MAS
                @NOMINATIV}
              @(TAU_PRED_DET INDEF)
              @(SIGMA_DP exists extern)
              @ALPHA_DET.
 ----
```

In this entry of the indefinite article "ein" (a) the information concerning its semantic binding property has been added. In this case, it is an exitential quantifier being able to externally bind a pronoun.

```
 bauer   N * @(PRED_SUBST BAUER COUNT)
             @MAS
             @SG
             { @NOM_OR_AKK
              |@DATIV}
             @(TAU_SUBST PAYSAN)
             @ALPHA_REF.
----
```

This is the entry of a normal substantive. Nothing special here, apart maybe the fact, that this entry has been qualified as being referential, in order to distinguish it from the following pronominal entry.

```
  er      PRO * (↑ PRED)='PRO_ANA'
                @MAS
                @SG
                (↑ AGR PERS)=3
                (σ↑ VAR)=PRO_ANA
                @NOMINATIV
                @(TAU_SUBST PRO_ANA)
                @ALPHA_PRON.
```

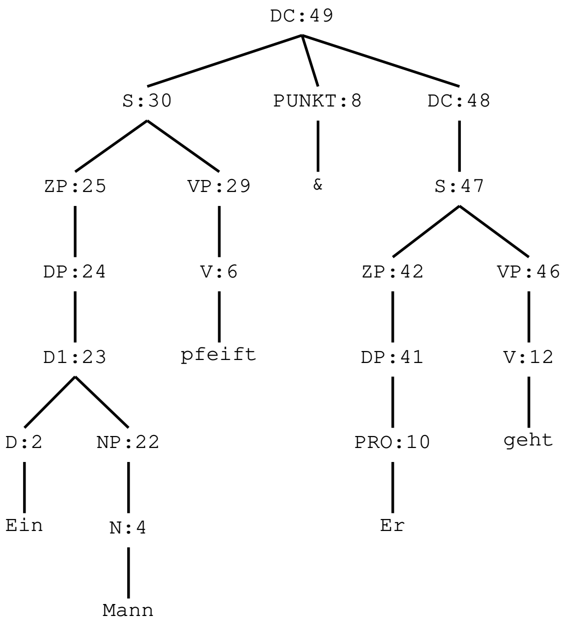
Pronouns are considered as acting like a variable, which can eventually be bound.

2.2 The Rule Component

A special rule for paragraph structures has been written. The main point here being described by the modular template "ANA_BIND" which allows binding of cross-sentential anaphora, if certain conditions are respected. How the annotation works can be seen on the display of the *f*-structure below. A special character "&" has been used in order to simulate the fullstop between the two parts of the (mini) discourse.

```
DC → S: (↑ ERSTER_SATZ)=↓
        @DISKURS
        (τ↑ ERSTER_SATZ)=τ↓
        (σ↑ ERSTES_ARG)=σ↓
        (α↑ ANTE)=α↓
        (τα↑ ANTE)=τα↓
        @ANA_BIND;
     (PUNKT: ↑=↓;
      DC: (↑ SATZ_FORTS)=↓
          (τ↑ SATZ_FORTS)=τ↓
          (σ↑ ARG_FORTS)=σ↓
          (α↑ ANTE_FORTS)=α↓
          (τα↑ ANTE_FORTS)=τα↓).
```

The structure produced by the rule is the following one:



Remember that my treatment has been realized on the basis of an already existing grammar. So I just adapted the semantic description to the syntactic analysis (for the motivation of this syntactic analysis, see [Berman 1995]).

2.3 The ϕ Projection

The augmented f-structure will basically represent information of the discourse structure. All other features have been taken over from the german grammar and are so long classical.

```
 [DISKURS       'OFFEN'
  PRED          'PUNKT'
                [PRED   'PFEIFEN<[24:INDEF]>'
                 TENSE  PRESENT
                        [PRED    'INDEF<[22:MANN]>'
                                 [GEN   MAS
                                  NUM   SG
                         AGR      PERS  3
  ERSTER_SATZ    SUBJ             CAS    72[GOV -
                                  71         OBL -]]
              30         24       [PRED   'MANN'
              29         23FCOMP 22 NTYPE  COUNT
              25          2       4 AGR          ]]
               6                                  ]
                [                [PRED   'GEHEN<[41:PRO_ANA]>'
                                  TENSE  PRESENT
                                         [PRED  'PRO_ANA'
                                                [GEN   MAS
                 ERSTER_SATZ                     NUM   SG
  SATZ_FORTS                      SUBJ     AGR   PERS  3
                                47                          
                                46                CAS   75[GOV -
                                42          41              OBL -]
                                12          10   74              ]]]
49                                                                
 8              48PRED          73[DISKURS 'ABGESCHLOSSEN']        ]]
```

2.4 The τ Projection applied on the f-Structure

On the base of the former f-structure, a τ-projection is applied and returns a t-structure, which is transfer based.

```
[DISKURS       'OUVERT'                                                    ]
[PRED          'POINT'                                                     ]
[              [PRED   'SIFFLER<[23:INDEF]>'        ]                      ]
[              [TENSE  PRESENT                      ]                      ]
[              [        [PRED    'INDEF<[22:HOMME]>']                      ]
[ERSTER_SATZ   [        [AGR      [NUM  SG]         ]                      ]
[              [SUBJ    [     105 [PERS 3 ]         ]                      ]
[              [        [        22[PRED 'HOMME']   ]                      ]
[            30[      23[FCOMP    4[AGR         ]   ]                      ]
[             6[       2[                           ]                      ]
[              [PRED       106[DISKURS 'CLOS']                            ]]
[              [                [PRED   'MARCHER<[41:PRO_ANA]>'           ]]
[SATZ_FORTS    [                [TENSE  PRESENT                           ]]
[              [ERSTER_SATZ     [         [PRED  'PRO_ANA'  ]             ]]
[              [                [SUBJ   41[AGR     [NUM  SG]]             ]]
[49            [              47[       10[    107 [PERS 3 ]]             ]]
[ 8          48[              12[                                          ]]
```

There is still an error in this description: the value of the AGR feature of the pronoun should be unspecified and will be calculated first at a next level.

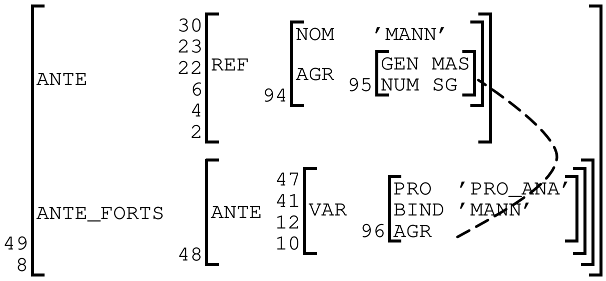
2.5 The σ Projection

The *s*-structure reflects basically the predicate-argument structure with the additional dynamic semantic interpretation: the existential quatified expression will be encoded as being externally dynamic ([DYN = extern]) and the pronoun is encoded as a variable.

```
[JUNKTOR      'diskurs-coord'                                 ]
[             [REL    PFEIFEN                   ]             ]
[             [     24[ARG   'MANN'  ]          ]             ]
[ERSTES_ARG 30[ARG1 23[DYN   extern  ]          ]             ]
[           25[     22[QUANT exists  ]          ]             ]
[            6[      2[              ]          ]             ]
[             [               [REL    GEHEN               ]  ]]
[ARG_FORTS    [ERSTES_ARG   47[                           ]  ]]
[49           [             42[ARG1  41[VAR PRO_ANA]      ]  ]]
[ 8         48[             12[      10[           ]      ]  ]]
```

2.6 The δ Projection

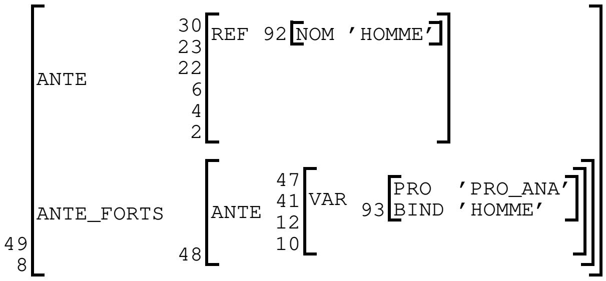
Abstracting again, we are now describing the specific discourse information. In the case of a possible anaphorical reading and in the case the semantic agreement features can unify (see the dotted line), the following discourse structure will be produced:



The pronoun gets no "REF" feature but a "BIND" feature, which value is the same as the "REF" feature of the referential expression in the former sentence.

2.7 The τ Projection applied on the d-Structure

And applying a τ-projection to this structure, a t-structure will be produced, which describes the resolution of the pronoun. The generation component of the grammar will dann have to select the correct item for the pronoun, which is at this level still underspecified.



The selection will be done in accordance with the semantic agreement features of the referential expression of the first sentence of the target language. So first at this level, the specification of the AGR feature of the pronoun can take place.

3 Conclusions

In this paper I described an implementation of the dynamic semantic interpretation of cross-sentential anaphora. The "information-passing" approach has been simulated within the LFG-formalism.

But still more than this has been done, and in fact the treatment of donkey sentences and of all the connectives of the first-order predicate logic has been provided.

Also in the case of the resolution of cross-sentential anaphora, more has been done. For example, where the unification of the semantic agreement features is not possible, a deictic and/or a generic reading of the pronouns is provided.

This shouldn't hide the fact, that the implementation is far away of being complete and elegant. The implementation has been stopped already a certain time ago and couldn't be improved because of lack of time.

Nevertheless some conclusions can be drawn. It has been shown, that the implementation of the DPL approach in a unification-based formalism can be done easily. In the case of the LFG-formalism, I used the specific expressions of the system and made an extensive use of the different representation levels whith the possibility of applying transfer rules at every level. It is also very easy to describe the influence of dicourse relations on the interpretation of anaphora.

What I missed in the GWB was a text-handling component (see for this the treatment of the DPL approach within the ALEP platform), which renders the processing of paragraphs quite straightforward.

References

[Berman 1995] Berman, J., Franck, A. *Deutsche und Franzoesiche Syntax im Formalismus der LFG*, Niemeyer,1995.

[Bethke 1990] Bethke, I. *der die das* als Pronomen, 1990.

[Dalrymple 1990] Dalrymple, Mary. *Syntactic Constraints on Anaphoric Binding,* dissertation, University of Stanford, 1990.

[Declerck 1996] Declerck, Thierry. Dealing with Cross-Sentential Anaphora Resolution in ALEP. *Proceedings of the 16th Conference on Computational Linguistics*, Copenhagen, 280-286, 1996.

[Gamut 1991] Gamut, L.T.F., *Logic, Language and Meaning*, University of Chicago Press, 1991.

[Groenendijk 1991] J. Groenendijk & M. Stokhof, Dynamic Predicate Logic, in *Linguistics and Philosophy* **14**, p. 39-100, 1991

[Heim 1982] Heim, Irene, *The Semantics of Definite and Indefinite Noun Phrases,* dissertation, University of Massachussetts, Amherst, 1982.

[Kamp 1981] Kamp, Hans. A Theory of Truth and Semantic Representation. In J. Groenendijk, T. Janssen, and M. Stokhof (eds.), *Formal Methods in the Study of Language,*, Mathematical Center Amsterdam: 277-322, 1981 [reprinted in J. Groenendijk, T. Janssen, and M. Stokhof (eds.), *Truth, Interpretation and Information*, Foris, Dordrecht, 1-41, 1984.

[Kaplan & Bresnan 1982] Kaplan, Ronald M. and Joan Bresnan. Lexical Functional Grammar: A formal system for grammatical representation. In J. Bresnan (ed.), *The Mental Representation of Grammatical Relations.* Cambridge, Mass.: MIT Press, pp. 173-281, 1982.

[Kaplan 1989] Kaplan, Ronald M. The Formal Architecture of Lexical-Functional Grammar. *Proceedings of ROCLING II, Taipei, Republic of China, 1989.* Reprinted in: *Journal of Information Science and Engineering* 5, 305-322, 1989.

[Kaplan et al. 1989] Kaplan, Ronald M., K. Netter, J. Wedekind, & A. Zaenen. Translation by structural correspondence. *Proceedings of Fourth European Conference of the Association for Computational Linguistics,* UMIST Manchester, 272-281, 1989.

[Kasper 1992] Kasper, Walter. *Semantische Repraeasentation und LFG.* Arbeitspapiere des Sonderforschungsbereichs 340, 10, Universitaet Stuttgart, 1992.

[Rooth 1987] Rooth, Mats. Noun Phrase Interpretation in Montague Grammar, File Change Semantics, and Situation Semantics, in P. Gaerdenfors (ed.), *Generalized Quantifiers.* Reidel, Dordrecht, 237-268, 1987.

[Vater 1979] Vater, Heinz. *Das System der Artikelformen im gegenwaertigen Deutsch.* 2. edition, Tuebingen, 1979.