TALN 2001, Tours, 2-5 juillet 2001

Translation mismatches in lexically-driven FUDR-based MT

Towards standardization of lexicon formalisms for MT

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Résumé - Abstract

Nous proposons un formalisme lexical pour des architectures de transfert co-descriptives dirigées par le lexique qui définissent le niveau analytique des *structures superficielles sous-specifiées de la représentation discursive* (FUDRS) comme le niveau de transfert. Nous examinerons quelques exemples de non-concordance structurelle entre source et cible dont on sait que la représentation est extrêmement difficile et nous démontrerons ainsi que ce formalisme permet de traiter un grand nombre de divergences structurelles dans le lexique. Par conséquent, cette approche permet de développer et d'entretenir le système de traduction d'une façon économique. En effet, les modules de transfert proprement dits peuvent rester simples et faciles à entretenir, étant donné qu'ils ne portent que sur les routines de transfert (et de génération) globales qui sont indépendantes des singularités du lexique.

We suggest a lexicon formalism for lexically driven, co-descriptive transfer architectures which assume transfer at the level of *flat underspecified discourse representation structures*. Considering the case of some notoriously difficult structural mismatches between source and target, we show that this formalism allows a wide range of structural divergencies to be treated lexically. As a consequence this enables economic system development and maintenance, because the built-in transfer modules can be kept lean and easy to maintain, as they can be restricted to global transfer (and generation) routines which are independent of lexical pecularities.

1 Introduction

Upgrading a (commercial) MT-system continuously is a very important task, which, as experience shows, is mostly a question of enlarging the lexica and the transfer knowledge respectively, given that source- (analysis-) and target- (generation-) grammars are normally relatively stable and complete from the first release on. The problem of MT-architectures with, say 'weak' bilingual lexica is that upgrading means upgrading the lexicon **and** the transfer grammar, which means that the lexicographer (very often a human translator) must be familiar with the transfer module/grammar and must maintain the transfer routines, or that there is someone permanently in charge of this. Neither alternative is desirable. Costs and instability are minimized if the lexicographer can use an expressive formalism which allows him or her to formulate most types of structural change lexically, such that the underlying transfer routine can remain stable. With regard to system architecture, this is the co-descriptive correspondance-based approach, where the source lexical items *co-describe* the corresponding target structure informations.

This approach is rather traditional and so far approved (see (Kaplan et al.1989), (Zajac1990), (Dalrymple et al.1995) and others). However, it is known that correspondance-based approaches can run into problems in case of structural divergencies between source and target, mainly with so called *head switching*-phenomena, as in (1):

(1) *a. Le bébé vient de tomber.*
b. Das Baby ist gerade herunter gefallen.
b. THE BABY JUST FELL.

Given that *venir* translates into *gerade/just*, the translation of the head of (a) is an adjunct of the head of (b), which is the translation of a complement of (a). Two elements exchange their positions in the structural hierarchy for each other, and, thus, destroy the homomorphic picture between source and target (see (Kaplan et al.1989) for the example). There is an ongoing discussion about this problem (see (Sadler and Thompson1991), (Kaplan and Wedekind1993), (Butt1994) and others). Common assumption is that the co-description approach using function-application and equality must fail when faced with embedded head switching structures (like *Peter thought that the baby just fell*), if formulated for the level of *syntactic* representation, including abstract syntactic descriptions like LFG's f-structures. This is so, because, at such descriptive levels, circular structures, or, to the same effect, contradictory path descriptions are unavoidable w.r.t. such cases, except one assumes unintuitive restriction operations. Note that the value of the sentential complement of the *thinking*, which is the *falling*-structure in the source, should be the translation of the adverb in the target, which should subsume the translation of the *falling*-structure, but **without** the adverbial substructure. However, there is no natural syntactic formal means which would allow for hierachically structuring the analysis into a sufficiently fine-grained set of substructures. [1]

We solve the problem by putting transfer up to the semantic level. There are several reasons why transfer at the level of semantic representation should be preferred to transfer of syntactic structures. We mention the correct translation of tense and aspect, which is much easier when the semantic analysis of the temporal relations of the text is available (see (Kamp and Rohrer1983), (Kamp and Rohrer1985), (Eberle et al.1992), (Eberle2000) for a motivation). Another reason is that the structural differences between the semantic representations of source and target can be expected to be less significant, when compared to syntactic analysis. A third reason is that the cyclicity problem turns into a question of semantic scope at the level of semantic representation, such that concepts like the *restriction operator* of (Kaplan and Wedekind1993), which are somehow artificial when formulated for syntactic representations (see also (Butt1994)), on the semantic level, can be formulated quite naturally as constraints about the relative scope of operators (see section 3 below). This result is important also insofar as it legitimates the

[1]Among other things, it is for this reason that most existing analytical, transfer-based Machine Translation systems distribute the transfer knowledge into relatively simple (conditioned) equivalence statements between source and target words, stored in the bilingual lexicon, and relatively fine-grained transfer knowledge about structural change, stored in the transfer module(s) proper. Some even renounce completely a bilingual lexicon and put all transfer knowledge in a transfer grammar.

For an overview to MT and its difficulties compare (D.J.Arnold et al.1994), (Arnold2000), for an evaluation of (commercial) systems compare for instance (Hess and Volk1999), also (Seewald-Heeg1995); (Wahlster2000) describes a recent research prototype; w.r.t to transfer, in particular, compare (Dorna and Emele1996).

lexically-driven co-descriptive architecture, which because of its advantages with respect to modularity, ergonomy and preference logic takes it over to graph rewriting approaches (see (Dorna et al.1998), compare also section 3).

However, the arguments for a semantics based transfer approach are practically validated only if the system can maximally avoid multiplying out those lexical and structural ambiguities which are irrelevant to translating the sentence. In other words the representations must be *under-specified* and must allow for dynamic semantic evaluation triggered by the transfer needs. In (Eberle2000) we presented a (German-French) translation system which meets these requirements. Its architecture is briefly outlined in the next section. [2]

2 Architecture

The system parses sentences into so called *slot grammar*-analyses (for the dependency oriented *slot grammar* theory and formalism see (McCord1989a)). ¿From these syntactic analyses, the system constructs *flat underspecified discourse representations* (FUDRSs), which are augmented by information from the syntax-semantics interface. We call these decorated FUDRs *dependence structures*. They define the level of transfer. [3] The transfer routine runs through the dependence structure, guided by the (semantic) ordering constraints of the sentence representation, translating the node structures by the specifications of the bilingual lexicon. (Basically, this means that the translation of (the flat semantics of) a non-deterministically chosen subcategorized slot or adjunct is chosen to be applied to the present argument translation, provided there is no other slot or adjunct which is known to have narrow scope w.r.t. the first one). ¿From the target dependence structure, the generation grammar constructs the target string, where this grammar (as well as the just described recursive transfer) may use source surface information and also may refine the semantic interpretation in order to render the output correct. [4]

Figure 1 renders this architecture, where the use of the LFG-typical projection symbols ϕ and σ should demonstrate the relative similarity to the LFG-approach (see (Kaplan and Bresnan1982), (Dalrymple et al.1995)).

However, we repeat it here, the dependence structure is a semantic representation, in contrast to LFG's f-structure. Therefore, in our approach, σ (triggered by lexical instructions and generation) is not a mapping between structures of different types, but a relation between structures of the same (semantic) type, but different semantic granularity. This is advantageous.

Basically, in slot grammar, a sentence is analysed into a head (the verb node), which is assigned a number of (subcategorized) *slots* (the verb complements) and, possibly, one or more adjunct modifiers (like subordinated clauses, adverbials, etc.). Given the sentence (2), (2.syn) renders

[2] The transfer system has been implemented (starting in 1996) and is part of the *Personal Translator* product line, whose technology has its roots in the LMT project (McCord1989b).

[3] FUDRSs have been introduced in (Eberle1997) mainly to complete Reyle's UDRT-approach (cf. (Reyle1993)) by an event semantic component, this is by an account of the quality and temporal structure of the sentence event(s) with regard to quantification, modalization and Aktionsart. *Flat* means among other things, that the lexical items are not analyzed further than into their predicate argument structure at first, but are connected to possibly more analytic disambiguated representations.

[4] Similar to approaches like *VerbMobil* (see (Kay et al.1994) for an overview), we assume that semantic evaluation, since costly, should be guided by transfer needs, instead of generally and globaly refining the underspecified basic dependence structures into readings of the sentences. Therefore the instruction formalism that we will sketch in section (3) allows for constraints containing elements which trigger such dynamic semantic evaluation.

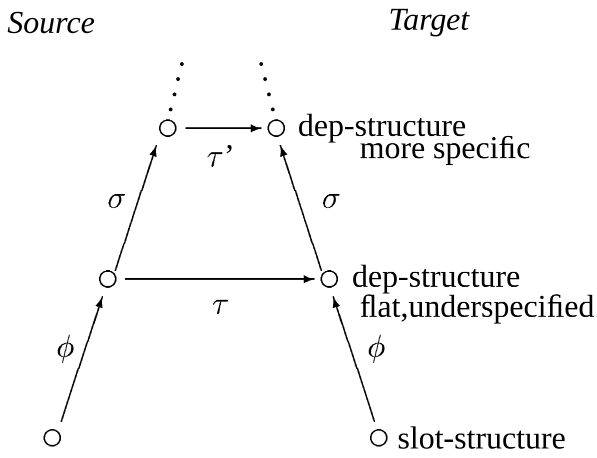

Figure 1: Relations

the corresponding analysis:

(2) *Pierre a donné Fido à Marie.*
PIERRE HAS GIVEN FIDO TO MARIE.

(2.syn) AVOIR [subj(n): PIERRE
aux(i): DONNER [obj(n): FIDO
iobj(n): MARIE]]

Here AVOIR, PIERRE, ... are the analyses of the corresponding words in (2), this, mainly, is surface position information (node number) connected to common syntactic and morphologic information. ¿From (2.syn), the dependence structure (2.dep) evolves by flat semantic construction (which interpretes the auxiliary complex of sentences with analytic tense forms as tense and aspect information about an introduced event description and the like, see (Eberle2000)).

(2.dep)

donner { subj(n): pierre,
obj(n): fido,
iobj(n): marie } & OC

(2.dep) has to be read as follows: donner, pierre, ... are the *flat* semantic representations of the corresponding words in the sentence (that is: decorated by relevant distinguished referents, tense and aspect information and connected to possible, more specific interpretations). The elements of the set are semantic functors with respect to the object heading the set, where a specific semantic interpretation (a DRS) can be constructed by applying the functors in accordance with the scope constraints of *OC* and where the relators subj(n), obj(n) ..., via using information from the syntax-semantics interface, determine the kind of modification to apply. (In case the set of order constraints is empty, the order of the applications is not further determined). On the basis of this, it is easy to see, how the transfer routine τ should work by default: τ applied to (2.dep) should result into the target dependence structure (2.tdep).

(2.tdep)

$$\tau_n(\underline{\text{donner}}) \left\{ \begin{array}{ll} \tau_s(\text{subj(n)}): & \tau_n(\underline{\text{pierre}}), \\ \tau_s(\text{obj(n)}): & \tau_n(\underline{\text{fido}}), \\ \tau_s(\text{iobj(n)}): & \tau_n(\underline{\text{marie}}) \end{array} \right\} \text{ \& OC}$$

where τ_n is the transfer relation of node elements, this is, the translation of flat word semantics, basically the relation between source and target word, and where τ_s is the transfer relation of relators, translating for instance de-complements of nouns, *ncomp(p(de))*, *le mari de la femme*, into noun complements of case genitive, *ngen*, *der Mann der Frau*. The relative scope order, *OC*, should be preserved.

Summarizing, the basic default transfer algorithm we use can be sketched by the following formula:

$$\tau(\text{Mother} \left\{ \begin{array}{ll} \text{slot}_1: & \text{Daughter}_1, \\ \vdots & \\ \text{slot}_n: & \text{Daughter}_n \end{array} \right\} \text{ \& OC})$$

$$:= \tau_n(\text{Mother}) \left\{ \begin{array}{ll} \tau_s(\text{slot}_1): & \tau(\text{Daughter}_1), \\ \vdots & \\ \tau_s(\text{slot}_n): & \tau(\text{Daughter}_n) \end{array} \right\} \text{ \& OC}$$

This allows for translating source sentences into target sentences, which, w.r.t. the level of dependence structure, are isomorphic.

3 τ-Instructions

The formal means that we suggest in the following extend the basic settings of the LMT lexicon formalism (see (Bernth1992)). A relevant (economic) feature of this is that saying nothing about the translation of a specific slot, slot_i, of an item means: translate it by default, this is by $\tau_s(\text{slot}_i)$. A prerequesite of this is to keep track of positional information. For this reason, we deviate slightly from the description style of (2.dep) and (2.tdep) by rendering the set of subcategorized modifiers as ordered set, that is, as a list. Next to the source setting (of the thus revised type (2.dep)), marked by •, and the corresponding target setting, τ, the considered part of a bilingual lemma, as a third component, may contain conditions, C, which restrict the acceptance of the presented translation to source structures satisfying C. For the example (2), therefore, we will write:

• <u>donner</u> [subj(n),obj(n),iobj(n)]

C: true

τ : <u>geben</u>

This means that *donner* has a 3-place reading which is translated into *geben*, without further preconditions, where the slots are translated isomorphically (according to τ_s), with values as defined by the corresponding lexical entries and the source dependence representation. ¿From this isomorphic default case, we can deviate by combinations of the following local and non-local τ-instruction types.

3.1 Local τ-instructions

We assume the following basic local instruction types:

T1 τ modifies the function of a slot: $\tau(slot_i) \neq \tau_s(slot_i)$

T2 τ suppresses a slot: $\tau(slot_i) = e$

T3' τ introduces a slot: *item(slot_name,slot_descr*$_{1-4}$*)*

item has at least two arguments, where the first defines the new slot and the second its value (the new word and its relation to the semantic argument). Additionally, semantic type information about the new item may be given. Finally, in recursive manner, information of slots and modifiers of the new item may be given. Therefore, via *item*, descriptions of entire (V-, N-, A-...) **phrases** can be introduced.

The local instruction types also include the following generalization to adjuncts and paths (over adjuncts and subcategorized modifiers):

T3 τ introduces an adjunct:
item(adjct_name,adjct_descr$_{1-4}$*)*

T4 τ shifts a s-dpath into a t-dpath:
tp(s-dpath,t-dpath)

Path shifting statements of type T4 are restricted to downward paths (d) including the empty path (e) at the target position.

Instead of illustrating these means by corresponding examples we turn directly to the more relevant non-local instructions and to the considered structural difficulties and their definitions which will make use of the types T1-T4 also.

3.2 Non-local τ-instructions

Non-local instructions speak about positions which are outside the structure which is (syntactically) dominated by the lexical item considered. One of these instructions allows for *upward path shifts* which are just renamings of the role the value plays w.r.t. its argument (in the semantic sense) in the target structure:

T4' τ shifts a s-upath into a t-upath:
tp(u(s-mod),u(t-mod))

(3) exemplifies this: the role played by the adjective changes in transfer.

(3) *Un médecin auxiliaire*
Ein Hilfsarzt
AN ASSISTANT DOCTOR

In the target, it is not an adjectival attribute of the head noun (*nadj*), but a compound of it (*ncompound*). We could render this change within the entry of *médecin*, via a T4 *tp(d(nadj),d(ncompound))*-statement. However, since the change does not really depend on the head noun, but is rather an intrinsic quality of *auxiliaire*, we will incorporate it in the entry of the adjective, as follows:

• auxiliaire []
C: u(nadj) - f
τ : ui('Hilfs-') [tp(u(nadj),u(ncompound))]

There are 3 other types of non-local instructions:
Provided N names a (source) structure (directly or via a path description), and M the lexical entry:

T5 τ uses a structure which is coreferent to τ(N):
$\ldots\tau$(N)$\ldots$

T6 τ uses the translation of a substructure of N in the scope of M, $N^{\not\succeq M}$:
$\ldots\tau(N^{\not\succeq M})\ldots$

T7 τ constrains a distant node:
τ(N): τ_constraints

More precisely, T6 means to use a structure N whose semantic functors allow for having narrow scope with respect to M and which are constrained accordingly by the σ-evaluation, when they undergo a corresponding specific τ-application.

Types T5 and T7 allow the treatment of the *verb to adverb* switching case ('a' to 'b' in (1)):

• venir [subj(n),obj1(infde)]
C: mtv(M,TF,a) & d(obj)-w(V)
τ: τ(V) &
V: [item(vadv,gerade,temploc_adv), tp(u-d(adjt),d(adjt))]
& mtv(M,perf(TF),a)

This means: given the obj(infde) of *venir* is V and *venir* has mood M (infinitival, finite,…), tense features TF and voice *a*ctive, we translate *venir* into the translation of V, where this translation obtains a new adverbial modifier *gerade*, takes over the adjuncts of *venir*, if any, and inherits the mtv-features of *venir*, with TF replaced by its perfective variant.

We use type T6, in order to specify the opposite case of switching ('b' to 'a' in (1)):

• gerade
C: u(vadv) - f & dst(temploc_adv)
τ: venir [item(subj(n),τ(u-d(s_subj))), item(obj(infde),$\tau(u^{\not\succeq id})$)]

This means that *gerade* is translated into *venir*, provided it modifies a verb V and *can be shown by semantic evaluation* – this is the meaning of 'dst' – to be a temporal modifier in the actual context, where the subject of *venir* will be the translation of the (surface) subject of the modified verb and where the object of *venir* is the translation of a structure, which syntactically is headed by V (and which is the value of the path u) and which, semantically, does not omit a functor which is known to have narrow scope with respect to *gerade*. (*id* designates the node of the item considered). In addition, this translation comes as infinitival complement. Its subject, which is coreferent to the matrix subject, is not realized on the surface.

These non-local means are very powerful and allow for specifying nearly all types of structural divergency. Due to lack of space, one last example is given which uses a wide variety of means.

(4) *Nous devons tourner et retourner ce sujet.*
Wir müssen dieses Thema von allen Seiten betrachten.
WE MUST INSPECT THIS SUBJECT FROM ALL ANGLES.

- retourner [subj(n),obj1(n),iobj(n)]

C: w(A) & u(rconj) - (w(H) & u-modal_verb & d(lconj) - tourner
& ¬(d(adjt)-f))
& u-d(obj)- (idée | plan | projet)
& ¬(d(iobj)-f) & ¬(d(adjt)-f)

τ : beleuchten[item(comp(p([von|dat])),[[seite|f],det(all,pl)]),x]
H:t(A)

Provided *retourner* is embedded in a V coordination structure as described by (4), without further modifications, as argument of a modal verb, the coordination is contracted to the translation of the right node (*beleuchten*) and is extended by a prepositional phrase (*von allen Seiten*).

Of course, the lexicographer might define templates for frequently used complex τ-statements and write them into a normalization data base. For instance, when defining the template D1, in the *gerade* entry above, he/she can replace the τ-statement by the following shorter one:

τ: venir^{advtoverb}.

D1
advtoverb(infde) := [item(subj(n),τ(u-d(s_subj))),
item(obj(infde),τ($u^{\not\succeq id}$))]

Note that application of a rule like *advtoverb* normally changes the source dependence structure. It will explicitly list the dst-conclusions which have been drawn when proving that the cond-stipulations hold (monotonic mode); or can hold (non-monotonic mode). After application of the *venir*-reading of *gerade*, the source dependence structure will assume *gerade* to be a temporal location and it will assume some of the modifiers of the verb modified by *gerade* to be in the scope of *gerade*, and the others to be outside. Of course, this might influence the choice of transfer equivalents of the items which are still to be processed. [5] On the basis of the recursive transfer definition (which by its default homomorphic character carries over scope relations of the source to the target and the like), it guarantees consistency of source and target in each moment of processing.

As a side-effect of the lexically driven recursive transfer strategy, a default logic falls out which orders the non-deterministically chooseable alternatives by preferring information from a node A to (conflicting) information of a node B, iff, according to the dependency hierarchy of the analysis, A is more specific than B. For example, the following bilingual information about the

[5] Thus, the translation of *mit Maria* in *Mit Maria ist Peter gerade angekommen* will depend on whether the PP has scope over the adverbial or not. In the first case, it will be translated by *Comme Maria* (*Comme Maria, Peter vient d'arriver/Peter just arrived, as Maria did*), in the second case it will be translated by *avec Maria* (*Peter vient d'arriver avec Maria/Accompanied by Maria, Peter just arrived*).

French preposition *à*:

- aller

C: true

τ: gehen[tp(d(prep(à)-st(COUNTRY),d(prep(nach))]

- États Unis

C: true

τ: Vereinigte Staaten
[tp(u(prep(à)-st(MOTIONV),u(prep(in))]

The first definition is part of the entry of the verb *aller* and stipulates that an *à*-adjunct, when added to the *aller*-VP, is translated into German *nach* in the context *C1*, *aller* **à** COUNTRY. The second definition presents the translation of *Etats Unis*. Additionally, it deals with the case(s) of specific translations of prepositions which are triggered by the use of *États Unis* as internal argument, where in the context *C2*, MOTIONV **à** *Etats Unis*, à is translated into *in*. Given the corresponding sentence analysis, where the restrictions of both translation variants are satisfied, the translation *in* will be preferred, because it stems from the more specific node and overrides the conflicting information of the higher node.

4 Concluding remarks

We would like to emphasize again that an important motivation for a bi- (or multi-) lingual lexicon with an expressive co-descriptive component, as is suggested in this paper, is to free the lexicographer from engineering tasks and, by this, to contribute to efficient system development and maintenance. In addition, it provides a preference logic for the corresponding transfer system which 'falls out' of the architecture as such and which, therefore, can be obtained for competing architectures (of the graph rewriting type for instance) by additional statements about the relevant *stalemate* situations only (which are frequent). The definition of templates allows the lexicographer to accelerate the conception of the transfer co-descriptions and to enhance readability of the lexicon entries. The principle that semantic disambiguation is guided by transfer needs, triggered mostly by the evaluation instructions about semantic type and scope of the lexical entries, guarantees the runtime economy of the system.

Acknowledgements

Thanks to Hans Kamp and Uwe Reyle and the other members of the former semantics group of IMS Stuttgart for discussions about the FUDR-formalism; special thanks to Chantal Cervoni and Christiane Sturm of linguatec E&S for help with the choice and working out of the examples. Also I wish to thank Hubert Lehmann of linguatec E &S for providing the time I needed to write down the paper.

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