Machine Translation and Complex Predicates*

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Abstract. The correspondence and restriction based approach to machine translation of Kaplan et al (1989) is expanded in Kaplan and Wedekind (1993) to include a treatment of complex predicates. Complex predicates pose the kind of problem usually described under "head-switching" because their syntax and semantics are non-isomorphic. Kaplan and Wedekind's (1993) solution involves a *restriction operator* in combination with a lexical rule which imposes constraints for complex predicate formation on the lexical entries of the main verbs. However, I show that this solution is inadequate for a more general treatment of complex predicates and propose a utilization of the resource logic approach (Dalrymple, Lamping and Saraswat 1993; Dalrymple et al 1993) to provide the flexibility necessary for the syntax/semantics mismatch exemplified by "head-switching" phenomena.

Der korrespondenz- und restriktionsbasierte Formalismus für maschinelle Übersetzung (MÜ) von Kaplan et al (1989) wird in Kaplan und Wedekind (1993) ausgebaut, um eine Behandlung komplexer Prädikate zu ermöglichen. Da die syntaktischen und semantischen Strukturen komplexer Prädikate nicht isomorph sind, stellen sie die MÜ vor die Problematik, die als *head-switching* bekannt ist. Kaplan und Wedekinds (1993) Lösung benutzt einen *Restriktionsoperators* und eine lexikalische Regel, die die lexikalischen Einträge aller Hauptverben durch die Spezifizierung von *constraints* einschränkt. Ich zeige aber, daß diese Lösung einer generelleren Behandlung komplexer Prädikate nicht gerecht wird, und formuliere einen flexibleren Ansatz, der auf den *resource logic* Ansatz von Dalrymple, Lamping und Saraswat (1993), Dalrymple et al (1993) aufsetzt.

1 Introduction

Complex predicates (e.g., causatives, passives) are charaterized by a complex semantics which cannot be placed in a straight forward one-to-one relationship with the syntax of the construction. A well known example are the Romance "restructuring verbs" like *volere andare* where the two verbs clearly each make a separate semantic contribution of their own, but behave as if they combine to form a single predicate with respect to phenomena like clitic climbing. That is, the predicates do not each head a clause, but head a single clause together.

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Within machine translation such a mismatch between the syntax and semantics of a construction often leads to the problem described as "head-switching". The predicate which appears to be the main semantic contributor (the head) in adverbial or control constructions in one language does not correspond to the head of the corresponding construction in another language. An example is shown in (1), where the head of each sentence is shown in bold-face.

(1) a. John **likes** to swim.
    b. John **schwimmt** gerne.

Kaplan et al (1989) and Kaplan and Wedekind (1993) advance a solution to such "head-switching" problems within the framework of Lexical-Functional Grammar (LFG). This *Correspondence and Restriction based-approach* (COREST) to machine translation takes advantage of an architecture in which the mappings, or correspondences, between various levels of linguistic structures are used to "co-describe" a given utterance. The additional functions τ and τ' relate source and target language representations. Translation is thus accomplished by specifying and resolving a set of constraints.

However, as Sadler et al (1989) and Sadler and Thompson (1991) point out, while the COREST approach offers many attractive features, it is not quite expressive enough to deal with the greater range of control constructions they consider. In response, Kaplan and Wedekind (1993) introduce the notion of a *restriction operator* and claim that the use of this operator allows not only a comprehensive treatment of adverbial modification and control constructions, but also of other types of complex predicates. In particular, a treatment of a rather interesting complex predicate construction in Urdu[2] is attempted.

I examine data from Urdu more closely and show that the initial contention of Sadler and Thompson (1991) is indeed well founded. I suggest that the key to a successful treatment of complex predicates and headswitching phenomena lies in recognizing and properly representing the mismatch between syntax and semantics in the source language. This can only be achieved by calling the sequential architecture underlying the LFG approach of Kaplan and Wedekind (1993) into question and by moving towards a more flexible architecture. I build on the proposals for semantic represenation formulated by Dalrymple et al (1993a), and Dalrymple et al (1993b) in terms of linear logic, and combine these with the LFG approach to complex predicates formulated in Butt (1993). Only once such an interactive architecture is in place, can the τ and τ' functions introduced by Kaplan et al (1989) be utilized successfully.

I should note that while this paper is couched within LFG, the overall point I make applies to all machine translation systems which assume that the syntactic and semantic representations of an expression are in a one-to-one correspondence, and that the semantics of an expression can therefore either be neglected, or be computed straight forwardly from the syntax. The issue of head-switching will remain problematic within machine translation as long as a possible mismatch between syntax and semantics is not taken into account.

[2] Urdu is widely spoken in India and Pakistan and is closely related to Hindi.

2 Complex Predicates

The type of complex predicate I consider here can be found in many natural languages, among them Italian, Spanish, French and Japanese – languages which have been central to work on machine translation. However, while much has been written on complex predicates in these languages (e.g., Rosen 1989, Manning 1992, Alsina 1993), a look at data from Urdu is very helpful as the facts here are not as complicated as in the Romance languages or in Japanese.

Butt (1993) shows that (2) must be analyzed as a complex predicate, but that the superficially similar sentence in (3) is a control construction.[3]

(2) a. anjum=ne saddaf=ko **ciṭṭ^{h}ii** [lik^h-ne **d-ii**]
A.F=Erg S.F=Dat letter.F=Nom write-Inf.Obl give-Perf.F.Sg
'Anjum let Saddaf write a letter.'
b. anjum=ne [**lik^h-ne d-ii**] saddaf=ko ciṭṭ^{h}ii
c. anjum=ne **d-ii** saddaf=ko [ciṭṭ^{h}ii **lik^h-ne**]
d. anjum=ne [ciṭṭ^{h}ii **lik^h-ne**] saddaf=ko **d-ii**

(3) a. anjum=ne saddaf=ko **ciṭṭ^{h}ii** [lik^h-ne=ko **kah-aa**]
A.F=Erg S.F=Dat letter.F=Nom write-Inf.Obl=Acc say-Perf.M.Sg
'Anjum told Saddaf to write a letter.'
b. anjum=ne [**lik^h-ne=ko kah-aa**] saddaf=ko ciṭṭ^{h}ii
c. anjum=ne **kah-aa** saddaf=ko [ciṭṭ^{h}ii **lik^h-ne=ko**]
d. anjum=ne [ciṭṭ^{h}ii **lik^h-ne=ko**] saddaf=ko **kah-aa**

Evidence for the complex predicate status of (2) comes from agreement, anaphora and control phenomena. For example, verbs in Urdu can agree with nominative subjects or objects, but the argument in question must be in the same clause as the verb. In (2) the finite verb *d-ii* agrees with the object *ciṭṭ^{h}ii*, while in (3) it does not. The permissive in (2) is therefore a syntactically simple construction, while (3) is syntactically complex.

The difference between the two constructions is not, however, reflected by syntactic phenomena such as scrambling or coordination. The scrambling patterns of (2) and (3) are identical: either the two predicates scramble together, or the infinitive predicate and its argument scramble together.

The complex predicate status of (2) is thus not reflected at phrase structure. Within an LFG approach a straight forward analysis is possible because the information about agreement, anaphora, and control can be encoded at f(unctional)-structure, a level which is independent, but constrained by c(onstituent)-structure where scrambling and coordination properties are represented.

Within this modular and constrained appraoch (see Bresnan (1982), Kaplan (1987) for a more detailed exposition) a straight forward treatment of complex predicates is possible because c-structure and f-structure representations

[3] Abbreviations used are as follows. F = feminine, M = masculine, Erg = ergative, Nom = nominative, Dat = dative, Acc = accusative, Inst = instrumental, Inf = infinitive, Obl = oblique, Perf = perfect, Sg = singular, Pl = plural. A '-' indicates a morpheme boundary, while a '=' separates a clitic from a lexical item.

are taken to be mutually constraining, but not one-to-one. The c-structures for (2) and (3) can therefore be identical, while the contrast between the complex predicate in (2) and the control structure in (3) is reflected at f-structure. This is shown in (4) and (5), respectively.

(4)

$$\begin{bmatrix} \textsc{pred} & \text{`let-write} < \textsc{subj}, \textsc{obj}_{go}, \textsc{obj} > \text{'} \\ \textsc{subj} & \begin{bmatrix} \textsc{pred} \ \text{`Anjum'} \end{bmatrix} \\ \textsc{obj}_{go} & \begin{bmatrix} \textsc{pred} \ \text{`Saddaf'} \end{bmatrix} \\ \textsc{obj} & \begin{bmatrix} \textsc{pred} \ \text{`letter'} \end{bmatrix} \end{bmatrix}$$

(5)

$$\begin{bmatrix} \textsc{pred} & \text{`say} < \textsc{subj}, \textsc{obj}_{go}, \textsc{xcomp} > \text{'} \\ \textsc{subj} & \begin{bmatrix} \textsc{pred} \ \text{`Anjum'} \end{bmatrix} \\ \textsc{obj}_{go} & \begin{bmatrix} \textsc{pred} \ \text{`Saddaf'} \end{bmatrix} \\ \textsc{xcomp} & \begin{bmatrix} \textsc{pred} & \text{`write} < \textsc{subj}, \textsc{obj} > \text{'} \\ \textsc{subj} & [\ \ ] \\ \textsc{obj} & \begin{bmatrix} \textsc{pred} \ \text{`letter'} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

This approach sucessfully covers all the syntactic facts of a complex predicate construction, but there is a problem in that the value for the PRED *let-write* in (4) appears as if by magic. It is a lexical entry which must be constructed dynamically from two distinct, syntactically separable predicates. In order to solve this problem, Butt (1993), Alsina (1993), Mohanan (1990), Andrews and Manning (1993) propose linguistic analyses in terms of complex predicate formation at argument (semantic) structure. A complex semantic structure like (6) is arrived at through *argument structure composition* and is then related to a "flat" f-structure like (4) by mapping processes (linking).

(6)

$$\begin{bmatrix} \textsc{rel} & \text{`let'} \\ \textsc{arg}1 & \text{`Anjum'} \\ \textsc{arg}2 & \text{`Saddaf'} \\ \textsc{arg}3 & \begin{bmatrix} \textsc{rel} & \text{`write'} \\ \textsc{arg}1 & [\ \ ] \\ \textsc{arg}2 & \text{`letter'} \end{bmatrix} \end{bmatrix}$$

The problem for machine translation can now be summarized as follows. There are two semantic heads in a complex predicate, which correspond to a single syntactic head. When translating the English predicates *let* and *write* into the Urdu *lik*^{h}*-ne di-yaa* the derived "lexical" entry must somehow be arrived at.[4]

[4] Note that since the permissives in Urdu are completely productive, a satisfactory solution is not to simply code every possible permissive construction in the lexicon.

3 Limitations of the Restriction Operator

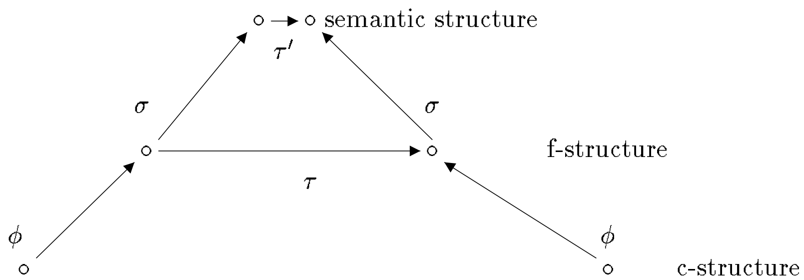
The type of problem outlined above is not confined to Urdu. In his treatment of derived verbs in German, Mayo (1993) defines a DPRED which triggers predicate composition at f-structure. Amores-Carredano (1994) similarly flags the base predicate in Spanish depictives and resultatives as incomplete (based on work by Alsina (1993)) and allows for the dynamic construction of a new PRED value in a machine translation system (JULIETTA) from English to Spanish.

This type of solution is exactly the right approach to complex predicates. However, the rather straight forward and relatively clean solution of replacing the value of an f-structure PRED by a more complex one can ultimately only work for trivial cases of complex predicate construction in which the argument structure of the base predicate is not affected. Thus, in *I hammered the metal flat*, the resultative *flat* contributes no additional argument. In cases like the Urdu permissive, on the other hand, each of the predicates contributes to the overall argument structure and the problem becomes not only one of predicate composition, but also one of argument structure composition.

Kaplan and Wedekind's (1993) view of the problem is quite different. Rather than composing two predicates into one, they propose to project the complex semantic structure in (6) from the flat, but lexically complex, f-structure in (4). They note that "there is a very clear intuition about what parts of the f-structure carry the information that constrains that piece of the semantic structure, namely, the sub-f-structure obtained by eliminating the SUBJ attribute and value." and formulate the restriction operator which picks out exactly the sub-f-structure ($f \backslash$SUBJ) corresponding to the ARG3 in (6).

While it may seem somewhat bizarre to construct a complex semantics from a compact syntactic representation, rather than the other way around, Kaplan and Wedekind are forced to this view by the architecture underlying their approach. They assume that f-structure is projected from c-structure by the function ϕ. S-structure in turn is projected from f-structure through the function σ. Source and target structures are related through a set of correspondences, parallel to the correspondences which hold between the levels of linguistic representation in a monolingual grammar. The complete system is shown in (7).

(7) Source Language Target Language



The formal device of codescription is utilized to specify the target structure constraints in terms of simple compositions of the τ and τ' mappings with the monolingual correspondences. Example (8) is taken from Kaplan et al (1989).

(8) Der Student beantwortet die Frage.
L'étudiant répond à la question.

Here the source and target predicates differ in the grammatical functions they subcategorize for. This difference can be handled quite simply by specifying appropriate mapping constraints in the entry for *beantworten* in (9).

(9) *beantworten* V ($\uparrow$PRED) = 'beantworten<($\uparrow$SUBJ), ($\uparrow$OBJ)>'
($\tau\uparrow$PRED FN) = répondre
($\tau\uparrow$SUBJ) = τ($\uparrow$SUBJ)
($\tau\uparrow$AOBJ OBJ) = τ($\uparrow$OBJ)

The attribute FN is used to designate the function-name in semantic forms such as 'beantworten<($\uparrow$SUBJ), ($\uparrow$OBJ)>'. Thus, the entry in the transfer lexicon ensures that the monolingual entry for *répondre* is looked up. On the basis of this lexical entry and the appropriate French entries for the noun phrases, an f-structure is built up and can be generated from.

When an appropriate translation is not possible on the basis of f-structure information alone, e.g. in cases of head-switching or structural non-correspondence, τ' may be used to relate the s-structures of source and target language. However, very little use of this function is actually made. In fact, instead of directly relating s-structures to one another through τ', as indicated in (7), the *restriction operator* is introduced to allow access to s-structure via the f-structure. The (partial) definition of this restriction operator is given in (10).

(10) If f is an f-structure and a is an attribute:
$f\backslash a \equiv f|_{Dom(f)-\{a\}} = \{< s, v > \in f | s \neq a\}$

The operator takes a given f-structure as input and results in an f-structure which has the attribute a and its value deleted from it. Partial f-structures and the semantic projections corresponding to them now become accessible.

Kaplan and Wedekind (1993) also propose that the restriction operator allows a clean solution to the syntax/semantics non-isomorphism problem posed by complex predicates as well. The restriction operator picks out exactly the sub-f-structure ($f\backslash$SUBJ) which corresponds to the embedded predicate *likʰ* 'write' in our examples. Complex predicates can now be dealt with by the introduction of a lexical redundancy rule which systematically modifies all main verbs to allow combination with a *light verb* such as the permissive *de* 'give'.

This rule essentially specifies what grammatical functions the arguments of a main verb are realized as when the semantic structure corresponds to a "subject-free-f-structure". Thus, the lexical redundancy rule introduces the constraints shown in (11) to the lexical entry of a main verb such as *likʰ* 'write'.

(11) (σ[$\uparrow\backslash$SUBJ] ARG1) = σ($\uparrow$OBJ$_{go}$)
(σ[$\uparrow\backslash$SUBJ] ARG2) = σ($\uparrow$OBJ)

While this allows a treatment of a simple Urdu complex predicate, the approach outlined above not only results in massive lexical redundancy, but also cannot be extended to cover other types of complex predicates.

The examples in (12) illustrate another kind of complex predicate involving "Aspectual light verbs". These light verbs make semantic and aspectual contributions to the predicate and determine the case-marking of the subject. Light verbs like *paṛ* 'fall' signal non-volitionality and require a nominative subject. Light verbs like *le* 'take' signal volitionality and require an ergative subject.

(12) a. **adnaan** ro **paṛ-aa**
Adnaan=Nom weep fall-Perf.M.Sg
'Adnaan fell to weeping (burst into tears).'

b. **adnaan=ne** ro **li-yaa**
Adnaan=Erg weep take-Perf.M.Sg
'He wept copiously on purpose.'

The fact that the light verbs determine the case marking of the subject show that the subject is an argument of the light verb, as well as of the main verb *ro* 'cry'. At f-structure, however, only one SUBJ can be represented (this follows from agreement, anaphora and control data).

(13)

$$\begin{bmatrix} \text{PRED} & \text{`weep-purposely} < \text{SUBJ} > \text{'} \\ \text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{`Adnaan'} \end{bmatrix} \end{bmatrix}$$

There is clearly a problem here since the subject-free-f-structure picked out by the restriction operator could not correspond to the semantic structure of the main verb *ro* 'cry': there are no grammatical functions left which could project to a piece of semantic structure.

Complex predicates in which differing kinds of light verbs are "stacked" illustrate a further problem. In (14) the main verb *banaa* 'make' combines with the Aspectual light verb *le* 'take'. This complex predicate then is combined with the permissive *de* 'let'.

(14) anjum=ne saddaf=ko g^har [[**banaa le-ne**] **di-yaa**]
A.F=Erg S.F=Dat house.M=Nom make take-Inf.Obl give-Perf.M.Sg
'Anjum let Saddaf make (build) a house (complete building).'

In order for the complex predicate *banaa le* 'complete building' to be able to combine with the permissive *de* 'let', the lexical rule would have to operate on the complex predicate itself. This implies creating lexical entries for all possible complex predicate combinations, so that the constraints governing further complex predicate formation can be specified.

Listing these differing constraints in the lexical entries of every main verb not only results in lexical redundancy, it also requires that all light verbs be specially marked as well. A more economical approach is one in which only the light verbs are marked as special. The constraints appropriate to complex predicate formation would then only be listed in the lexical entries of the light verbs, rather than in the lexical entries of the language's entire verbal system.

4 Resource Logic and Mapping

Dalrymple et al (1993b) show that the two central problems posed by complex predicate constructions, namely the syntactic monoclausality problem and the syntax/semantics non-isomorphy problem receive a clean and formally rigorous treatment monolingually based on an interpretation of the semantics through resource logic. In this approach a distinction is made between the *language of meaning* and the *language of assembling meanings* or *glue language*. Simple first order logic suffices for the former, while a fragment of linear logic is used for the latter. In this system, the composition of meanings is interpreted by deduction.

The lexical entry for a verb contains its semantic arguments, rather than its grammatical functions. Mapping principles relate the semantic arguments to grammatical functions at f-structure. This approach correctly allows for the linguistic fact that a verb's semantic arguments are not always realized as the same grammatical function. The following lexical entries for the main verb *lik*^{h} 'write' and the light verb *de* 'give' are based on Dalrymple et al (1993b).

(15) lik^h V $(\uparrow \text{PRED})=\text{`WRITE'}$
$\forall X, Y.\ agent((\uparrow \text{PRED})_\sigma, X) \otimes theme((\uparrow \text{PRED})_\sigma, Y) \multimap \uparrow_\sigma = write(X, Y)$

(16) de V $\forall X, Y, P.\ permitter((\uparrow \text{PRED})_\sigma, X) \otimes permittee((\uparrow \text{PRED})_\sigma, Y) \otimes$
$\uparrow_\sigma = P \multimap \uparrow_\sigma = let(X, Y, P)$

The linear multiplicative connective $\otimes$ is essentially equivalent to the standard conjunction $\wedge$, while the linear implication $\multimap$ is essentially equivalent to the standard implication $\rightarrow$. The treatment of complex predicates based on resource logic views light verbs as *consuming* the meaning of the main verb and its arguments and *producing* a new meaning, i.e., a permissive meaning in the case of *de* 'let'. The lexical entry for the light verb *de* thus specifies that it must combine with another predicate P. Mapping rules can now be formulated which relate the complex semantics to an f-structure representation.

There is, however, an interesting issue that arises with the directionality of the mapping rule as formulated by Dalrymple et al. The mapping principles they assume are based on purely linguistic principles (Bresnan and Kanerva 1989, Alsina and Mchombo 1989, Bresnan and Moshi 1990). These linguistic analyses assume an architecture in which the various levels of representation are independent, but mutually constrained so that a mapping from arguments to grammatical functions takes place rather than a mapping from f-structure to s-structure, as is assumed in the uni-directional architecture underlying the resource logic and the COREST approaches.

If the standard LFG view of independent and mutually constraining levels of representation is taken (see Butt (1993) for discussion), predicate argument relations at s-structure can still be arrived at unproblematically through a composition of meanings found in the lexical entries, as proposed in the resource logic approach. The mapping principle in (17) yields the right results: a number of semantic arguments are placed in correspondence with a subject, an object and an oblique in a given f-structure. Note that this rule also identifies the permissee (*Saddaf* in the examples above) as identical to the agent of the permitted action.

(17) $!(\forall f, X, Y, Z.\ permitter((f\ \text{PRED})_\sigma, X) \otimes permittee((f\ \text{PRED})_\sigma, Y) \otimes agent((f\ \text{PRED})_\sigma, Y) \otimes theme((f\ \text{PRED})_\sigma, Z) \multimap ((f\ \text{SUBJ})_\sigma = X) \otimes ((f\ \text{OBJ})_\sigma = Y) \otimes ((f\ \text{OBJ})_\sigma = Z))$

Mapping principles thus relate s-structure information to f-structures. The f-structure information in turn must be consistent with the set of functional equations that the c-structure is annotated with. This view of the architecture solves the problem of relating complex semantics to a flat f-structure because the correspondence between s-structure to f-structure need not be onto, but can be many-to-one, in parallel to the many-to-one correspondence function ϕ which relates f-structure representations to c-structures.

Having established a solid monolingual base, machine translation of complex predicates can now be implemented unproblematically through a utilization of the τ relation originally posited by Kaplan et al (1989). The transfer specification in the lexical entry for English 'write' thus looks as sketched in (18).

(18) *write* V $(\uparrow\text{PRED}) =$ 'write'
$\forall X, Y.\ agent((\uparrow\ \text{PRED})_\sigma, X) \otimes theme((\uparrow\ \text{PRED})_\sigma, Y) \multimap \uparrow_\sigma = write(X, Y)$
$(\tau\uparrow\text{PRED FN}) = lik^h$

The τ relation here merely relates the English entry to the corresponding Urdu predicate. Grammatical function information is not additionally specified, rather, grammatical function realization is dependent on language particular mapping principles which relate s-structure to f-structure. This approach thus has more of the characteristics of an interlingua than a transfer system and stipulative specifications on the idiosyncratic transfer of grammatical functions are avoided in favor of more general principles of mapping between argument (semantic) structure and grammatical functions.

5 Conclusion

Data from Urdu complex predicates serve to highlight the core issue underlying the problem which "head-switching" phenomena pose for machine translation. The syntax and semantics are non-isomorphic and are realized in differing syntactic structures from language to language. Complex predicates in particular require that a complex semantics be related to a monoclausal syntactic representation. This poses problems for architectures which are implicitly sequential. I propose an approach in which a deeper monolingual analysis yields a system of mapping principles which relate the semantic arguments of a construction to grammatical functions and not vice versa. This is crucial as the relationship between semantic arguments and grammatical functions cannot be assumed to be one-to-one. The constrained semantic representation of complex predicates in terms of resource logic (Dalrymple et al 1993b) in combination with mapping principles and the τ relation originally formulated by Kaplan et al (1989) allows a more flexible treatment to complex predicates which approximates an interlingua approach and avoids the stipulativity of a more transfer-based approach.

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