IDIOMS IN THE ROSETTA MACHINE TRANSLATION SYSTEM

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Abstract

This paper discusses one of the problems of machine translation, namely the translation of idioms. The paper describes a solution to this problem within the theoretical framework of the Rosetta machine translation system.
Rosetta is an experimental translation system which uses an intermediate language and translates between Dutch, English and, in the future, Spanish.

1 Introduction

Idioms have been and still are a basic theoretical stumbling block in most linguistic theories. For the purposes of machine translation or, in general, natural language processing, it is necessary to be able to deal with idioms because there are so many of them in every language and because they are an essential part of it.

Idioms occur in sentences as a number of words, possibly scattered over the sentence and possibly with some inflected elements; this number of words has to be interpreted as having one primitive meaning. For example, in (1) "made", "peace" and "with" have to be interpreted idiomatically. Note that words that are part of the idiom are underlined.

(1) He has made his peace with his neighbour

The classic example is (2):

(2) Pete kicked the bucket

Literally this sentence means that Pete hit a specific vessel with his foot. In the idiomatic reading the interpretation is that Pete died. It is impossible to infer this idiomatic meaning directly from the primitives "Pete", "kick", "the" and "bucket" and from the way they are combined.

Idioms can undergo syntactic transformations, but sometimes they are reluctant to do so. The passive sentence (3) has lost its idiomatic reading, while in the passive sentence (4) the idiomatic reading has been retained[1].

(3) The bucket was kicked by Pete
(4) Mary's heart was broken by Pete

Other examples are (5-12). In the idiomatic reading in (5) clefting with the object as focus is not allowed, while it is allowed in (6) if "Mary" is stressed. Clefting with the subject as focus in both (7) and (8) is permitted. In (9) the PP "at whose door" and in (10) the NP "whose heart" can be subject to wh-movement. In (11) the NP "Mary's heart" can be topicalized (if "Mary" is stressed), but in (12) the NP "the bucket" cannot undergo this transformation without losing the idiomatic reading. Thus idioms behave syntactically like non-idiomatic structures, although sometimes they are restricted[2].

(5) It was the bucket that Pete kicked
(6) It was Mary's heart that Pete broke
(7) It was Pete that kicked the bucket
(8) It was Pete that broke Mary's heart
(9) At whose door did Pete lay his failure
(10) Whose heart did Pete say that Mary broke
(11) Mary's heart Pete broke
(12) The bucket Pete kicked

Idioms can take free arguments or can have elements, like possessive pronouns, which have to be bound by arguments. In sentences (13-15) "Mary" is a complement to the idiomatic verb, and realizes different grammatical functions in the sentence (i.e. indirect object, possessive NP and to-PP object respectively). In (16) the pronoun "his" has to be bound by the subject "Pete".

(13) Pete gave Mary the finger
(14) Pete broke Mary's heart
(15) Pete laid down the law to Mary
(16) Pete lost his temper

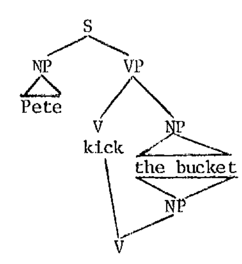
Linguistic theories on idioms should be able to account for the problems outlined above. The proposals made are usually fragmentary, in the sense that they only are concerned with part of the problem, for instance Fraser (1970), who only deals with the possible application of transformations to idioms, or they are a relatively minor part of a larger theory, for example Chomsky (1981), who gives a very general and principled account of idioms, but cannot cope with all the data. More elaborate studies on idioms are usually not directly relevant to machine translation, for instance Boisset (1978), who treats idioms from a more pragmatic point of view. To illustrate it could be argued that Chomsky (1981) can cope with sentences such as (2) and (15), but not with (13), (14) and (16); Pesetsky (1985) can deal with (2) or (13-16), but not with a sentence like:

(17) Pete laid his failure at Mary's door

Chomsky (1981, p. 146, note 94) claims that "we may think of an idiom rule for an idiom with a verbal head as a rule adding the string aVc to the phrase marker of each terminal string abc, where b is the idiom, now understanding a phrase marker to be a set of strings" and that idioms "appear either in D-structure or S-structure or LF-form." Furthermore "at D-structure, idioms can be distinguished as subject or not subject to Move alpha".

Thus here it is possible to reanalyse a string abc into aVc as for example for sentence (2) in figure (18), where the reanalysis is indicated by a double tree and where a is "Pete", b is "kick the bucket" and c is empty:

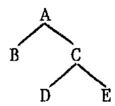
(18)



It seems that on this approach elements of idioms must be adjacent at a certain level (D-structure, S-structure or LF-form), which is the case for sentence (2). However, in sentence (14) the parts of the idiom "break" and "heart" are not adjacent at any level, since the free argument "Mary" is situated between the idiom parts and in (16) "lose" and "temper" are not adjacent at any level either. Hence this theory is not able to deal with every type of idiom.

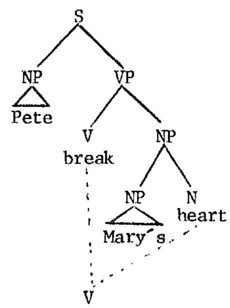
According to Pesetsky (1985) in a configuration such as figure (19) B and E may undergo a rule of idiosyncratic interpretation, if E is the head of C.

(19)



For sentence (14) in which "heart" is the head of the NP dominating "Mary's heart", the rule of idiosyncratic interpretation is allowed, resulting in:

(20)



In the above tree, the effect of the rule of idiosyncratic interpretation is indicated by the dotted lines; the effect is that the idiom parts are mapped onto one meaning.

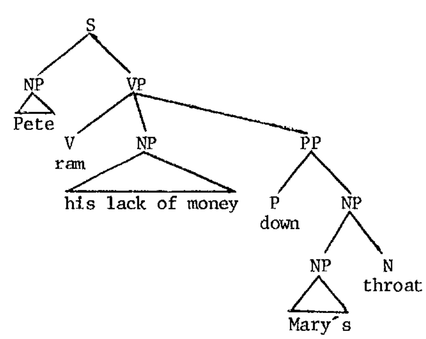
As suggested by Pesetsky, this would also account for sentence (13) if we follow Kayne (1982) in his analysis of double object constructions. Kayne claims that "NP the finger" forms a constituent with "the finger" as its head, so the rule of idiosyncratic interpretation is allowed.

Sentences (17) and (21-22) are problematic even under this analysis:

(21) Pete <u>rammed</u> his lack of money <u>down</u> Mary's <u>throat</u>
(22) Pete <u>gave</u> Mary <u>credit for</u> her work

Figure (23) gives a representation of sentence (21) in which "his lack of money" and "Mary" are free arguments:

(23)



Since "throat" and "down" are heads of their constituents, one might suggest a successive application of the rule of idiosyncratic interpretation, but it is not clear how such a rule should operate and since every constituent has a head and syntactic categories are no barrier to rule application, the domain in which this rule is permitted is unlimited.

It seems that Chomsky (1981) and Pesetsky (1985) are not capable of dealing with the counter examples given here. The treatment of idioms presented in this paper can cope with these phenomena because it is based on the assumption that elements of idioms neither have to be adjacent at the level of interpretation nor do they have to be in the specific configuration proposed by Pesetsky.

In the field of computational linguistics not much attention has been paid to idioms. Some examples are Rothkegel (1973) and Wehrli (1984). However, in their proposals idioms are treated in the lexicon or morphology and there is no apparent way to account for the scattering of elements of idioms in sentences.

The organisation of the rest of the paper is as follows: in section (2) an outline of the theoretical framework of the Rosetta machine translation system will be given; section (3) discusses idioms within this framework; section (4) discusses some of the typical problems mentioned in the introduction.

2 Outline of Isomorphic M-Grammars

The Rosetta system is based on the 'isomorphic grammar' approach to machine translation. In this approach a sentence s' is considered a possible translation of a sentence s if s and s' have not only the same meaning but if they also have similar derivational histories, which implies that their meanings are derived in the same way from the same basic meanings. This approach requires that 'isomorphic grammars' are written for the languages under consideration.

The term 'possible translation' should be interpreted as "possible in a particular context". The discussion in this paper will be restricted to the translation of isolated sentences on the basis of linguistic knowledge only.

In the following sections the notions M-grammars, the variant of Montague grammar used in the Rosetta system, and isomorphic grammars will be introduced. For a more detailed discussion of isomorphic M-grammars the reader is referred to Landsbergen (1982, 1984). In section (2.3) an example of an M-grammar will be given.

2.1 M-Grammars

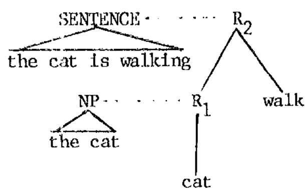
The grammars used in the system, called M-grammars, can be seen as a computationally viable variant of Montague Grammar which is in accordance with the transformational extensions proposed by Partee (1973). This implies that the syntactic rules operate on syntactic trees rather than on strings. Restrictions have been imposed on the grammars in such a way that effective parsing procedures are possible.

An M-grammar consists of (i) a syntactic, (ii) a morphological and (iii) a semantic component.
(i) The syntactic component of an M-grammar defines a set of 'S-trees'.
An 'S-tree' is a labelled ordered tree. The labels of the nodes consist of a syntactic category and a list of attribute-value pairs. The branches are labelled with the names of syntactic relations, such as subject, head, object, etc.
An M-grammar defines a set of S-trees by specifying a set of basic S-trees[3] and a set of syntactic rules called 'M-Rules'.
An 'M-Rule' defines a partial function from tuples of S-trees to S-trees.

Starting from basic expressions, an expression can be formed by applying syntactic rules. The result of this is a surface tree, in which the labels of the terminal nodes correspond to words. This process of making an expression is represented in an M-grammar by a 'syntactic derivation tree', in which the basic expressions are labels of the terminal nodes and the names of the rules that are applicable are labels of the non-terminal nodes. In the example below (Fig. (25)), rule R_1 makes the NP "the cat" from the basic expression "cat" and rule R_2 makes the S-tree for the sentence (24) on the basis of the NP and the basic expression "walk" (the constructions to the left of the dotted lines are abbreviations of what the result of the application of the rule looks like).

(24) the cat is walking

(25)



(ii) The morphological component relates terminal S-trees to strings. This component will be ignored in the rest of the discussion.

In this way the syntactic and the morphological component define sentences.

(iii) The semantic component. M-grammars obey the compositionality principle, i.e. every syntactic rule and every basic S-tree gets a model-theoretical interpretation. For translation purposes only the names of meanings and the names of meaning rules are relevant as will be shown later. The model-theoretical interpretation of the basic S-trees and the syntactic rules is represented in a ´semantic derivation tree´, which has the same geometry as the syntactic derivation tree, but is labelled with names of meanings of rules and basic expressions. An example is given below in (27).

Before giving an example of an M-grammar in section (2.3), isomorphic M-grammars will be discussed.

2.2 Isomorphic M-Grammars

To establish the possible translation relation the grammars must be attuned to each other as follows:

- For each basic expression of a grammar G of a language L there is at least one basic expression of a grammar G´ of a language L´ with the same meaning.
- For each syntactic rule of G there is at least one syntactic rule of G´ corresponding to the same meaning operation. Syntactically these rules may differ considerably.

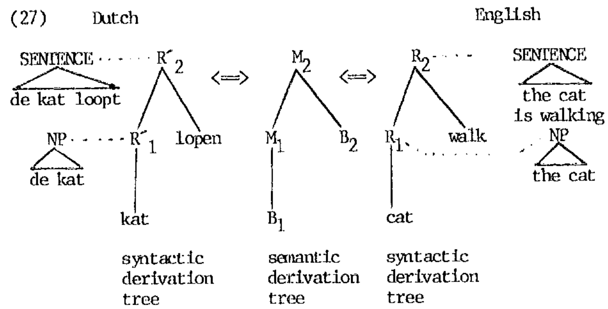
Two sentences are defined to be (possible) translations of each other if they have derivation trees with the same geometry, in which the corresponding nodes are labelled with names of corresponding rules and basic expressions. If this is the case then the derivation trees are isomorphic and the two sentences have the same semantic derivation tree.

Grammars that correspond to each other in the way described above will be called ´isomorphic grammars´ if the corresponding rules satisfy certain conditions on application, such that for each well-formed syntactic derivation tree in one language there is at least one corresponding well-formed syntactic derivation tree in the other language. A syntactic derivation tree is well-formed if it defines a sentence, i.e. if the rules are applicable.

The following is an illustration of these principles. The left part of figure (27) shows the derivation tree of sentence (26) which is the Dutch translation of sentence (24). Rule R'_1 builds the NP "de kat" from the basic expression "kat" and rule R'_2 constructs the expression "de kat loopt" from the NP and the basic expression "lopen". There is a correspondence between both the basic expressions and the syntactic rules of the two grammars. Each rule of the syntactic derivation tree is mapped onto a corresponding rule of the semantic derivation tree and each basic expression is mapped onto the corresponding basic meaning.

(26) de kat loopt

(27)



The Rosetta machine translation system is based on the isomorphic grammars approach. The semantic derivation trees are used as the interlingua. The analysis component translates sentences into semantic derivation trees; the generation component translates semantic derivation trees into target language sentences. In this paper the translation relation will be discussed generatively only.

2.3 An Example of an M-Grammar

In this section an example will be given of an M-grammar that generates sentence (28):

(28) Pete lends the girl a book

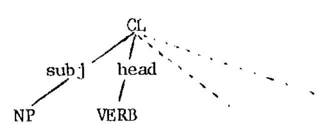
Only those M-Rules that are relevant to the discussion in the following sections will be dealt with. Note that the rules given here are in an informal notation.

The M-grammar needed for this example:

(i) basic S-trees:
VERB(lend)
(in this informal notation the syntactic information in the basic S-trees, given in the form of attribute-value pairs, has been omitted)
NOUN(Pete)
NOUN(girl)
NOUN(book)
VAR(x_1), VAR(x_2),...
(VAR´s are syntactic variables corresponding to logical variables)

(ii) M-Rules:
Some notational conventions:
- t_1, t_2, etc. are S-trees,
- mu´s indicate arbitrary strings of relation/S-tree pairs,
- square brackets indicate nesting,
- in an expression of the form det/ART(the) det is the relation, ART the category and "the" a literal.

So an expression like CL[subj/NP, head/VERB, mu1] stands for:



R_1 : if t_1 is of category VERB and
t_2 is of category VAR with index i and
t_3 is of category VAR with index j and

t_4 is of category VAR with index k
then: $CL[subj/t_2, head/t_1, iobj/t_3, obj/t_4]$

The rule operates on a ditransitive verb and three variables and makes a clause in which the variables are the subject, indirect object and direct object respectively.

R_2 : if t_1 is of category NOUN
then: $NP[head/t_1]$

R_3 : if t_1 is of category NOUN
then: $NP[det/ART(the), head/t_1]$

R_4 : if t_1 is of category NOUN
then: $NP[det/ART(a), head/t_1]$

$R_{5,i}$: if t_1 is of category NP and
t_2 is of the form $CL[subj/VAR(x_i), mu1]$
then: $CL[subj/t_1, mu1]$

This is a rule scheme with an instance for every variable index i. The rule substitutes an NP for the subject variable. The same holds for rules $R_{6,j}$ and $R_{7,k}$ in which the NP´s are substituted for the indirect and direct object respectively.

$R_{6,j}$: if t_1 is of category NP and
t_2 is of the form $CL[mu1, iobj/VAR(x_j), mu2]$
then: $CL[mu1, iobj/t_1, mu2]$

$R_{7,k}$: if t_1 is of category NP and
t_2 is of the form $CL[mu1, obj/VAR(x_k)]$
then: $CL[mu1, obj/t_1]$

R_8 : if t_1 has the form $CL[subj/NP, head/VERB, mu1]$
then: $SENTENCE[subj/NP, head/VERB, mu1]$

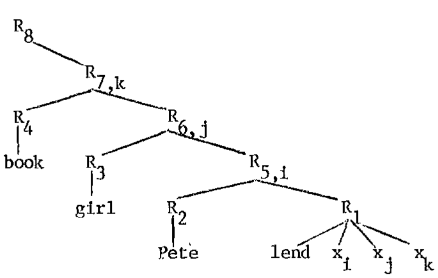
Apart from changing the category, this rule assigns the tense to the verb and specifies the form in accordance with the number and person of the subject, which is not indicated here (the correct form is spelled out in the morphological component).

In this example the rules operate as follows:

- Rule R_1 applied to "lend", $VAR(x_i)$, $VAR(x_j)$ and $VAR(x_k)$ as indicated,
- rule R_2 applied to "Pete" gives NP(Pete),
- R_3 applied to "girl" renders NP(the girl),
- R_4 applied to "book" NP(a book),
- rule $R_{5,i}$ applied to "lend" and NP(Pete) renders CL(Pete lend x_j x_k),
- application of $R_{6,j}$ to "lend" and NP(the girl) renders CL(Pete lend the girl x_k),
- application of $R_{7,k}$ to "lend" and NP(a book) results in CL(Pete lend the girl a book),
- application of R_8 gives SENTENCE(Pete lends the girl a book).

The derivation tree for this example is represented in (29):

(29)



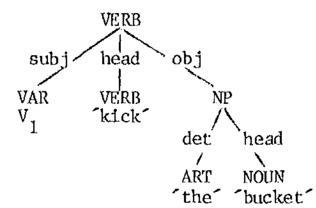
3 Idioms and Isomorphic M-Grammars

Traditionally, in Montague semantics, as for instance in the PTQ paper (Montague, 1973), a basic expression has a primitive meaning. However, the semantic concept basic expression does not always coincide with what one would call a syntactic primitive. This is the case, for instance, with idioms. For example the idiom "kick the bucket" has the primitive meaning ´die´, but the syntactic primitives are "kick", "the" and "bucket".

For reasons given in the introduction it is impossible to treat idioms as strings (i.e. syntactic primitives). The possibility of applying syntactic transformations to (elements of) idioms, which are also applicable to non-idiomatic constructs, suggests that idioms should be treated as having complex constituent structures, which are similar to non-idiomatic constituent structures. The possibility of having free arguments, which are realized by various grammatical functions, suggests that parts of idioms do not have to be adjacent at any level of the syntactic process. The complex idiomatic constituent structure should accommodate this.

In Rosetta, before idioms were introduced, basic expressions were terminal S-trees, i.e. terminal nodes. Idioms can be treated as basic S-trees that have an internal structure. This type of expression is an example of what will be called a ´complex basic expression´ (CBE). A CBE is a basic expression from a semantic point of view, i.e. it corresponds to a basic meaning, and a complex expression from a syntactic point of view, i.e. it is a non-terminal S-tree. For example, the basic S-tree for "kick the bucket" looks like the following:

(30)

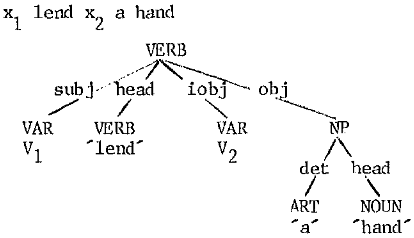


By extending the notion of basic expression in this way the attuning of grammars (as defined in section (2.2)) is easier to achieve: corresponding basic expressions may be CBE´s. For example the Dutch verb "doodgaan" may correspond to the English idiom "kick the bucket". Special measures are necessary to guarantee that the rules obey the conditions on application (cf. section (2.2)).

Basic expressions are listed in the basic lexicon of a grammar. A CBE is represented as a canonical surface tree structure in the lexicon. A canonical surface tree structure is the default tree structure for a certain sentence, phrase, etc., i.e. the structure to which no syntactic transformations have applied. For example: if there is a passive transformation, the canonical structure is in the active form. Figure (32) shows the lexicon representation of the idiom:

(31) x_1 lend x_2 a hand

(32)



The VAR nodes are not specified (i.e. not referring to an actual VAR) in the dictionary. These variables will be replaced by syntactic variables, when the CBE is inserted into the syntactic tree. Apart from the category VERB and the usual attribute-value pairs, the top node contains a set of attribute-value pairs that indicates which transformations are possible.

3.1 Treatment of Complex Basic Expressions

In this section an extension of the M-grammar of section (2.3) will be given that can deal with an interesting class of Complex Basic Expressions and two M-grammars will be related to each other according to the isomorphy approach. Some other reasons for having complex basic expressions will be given.

3.1.1 An Example of an M-grammar for Complex Basic Expressions

In this section an M-grammar will be presented that generates the idiomatic sentence:

(33) Pete lends the girl a hand

The grammar of section (2.3) is extended in the following way:

(i) basic S-trees
VERB(V_1 lend V_2 a hand)

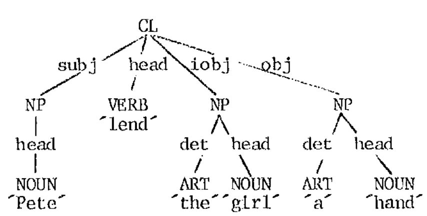
(ii) M-Rules:
R_9 : if t_1 is of the form VERB[subj/V_1, head/VERB, iobj/V_2] and
t_2 is of category VAR with index i and
t_3 is of category VAR with index j
then: CL[subj/t_2, head/VERB, iobj/t_3]

This rule expects a complex, transitive verb and two variables; it constructs a clause in which the variables are the subject and the indirect object.

For this example the rules operate as follows:
- R_9 renders CL(x_i lend x_j a hand),
- R_2 and R_3 as in section (2.3),
- $R_{5,i}$ renders CL(Pete lend x_j a hand),
- $R_{6,j}$ gives CL(Pete lend the girl a hand),
- rule R_8 results in CL(Pete lends the girl a hand).

The derivation tree for this sentence is represented in the left part of figure (37).

The result of application of rules R_9, R_2, R_3, $R_{5,i}$ and $R_{6,j}$ is represented as a tree structure in figure (34):

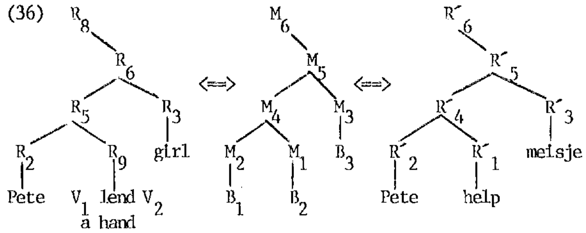
(34)


This construct is similar to the construct made after applying rules R_1 to $R_{7,k}$ in the example of section (2.3). One of the basic expressions differs. So the structures can be idiomatic or non-idiomatic and other rules of the M-grammar (e.g. wh-movement or passivisation) are applicable to both these structures, unless, as in the case of certain idioms, they are prohibited as indicated at the top node.

3.1.2 Complex Basic Expressions and Isomorphic Grammars

Assume we have an M-grammar that generates the Dutch sentence (35) which is a translation of (33). It is then possible to let the English M-grammar given above for (33) correspond to this grammar in the following way:

(35) Pete helpt het meisje

(36)


Here "Pete" in both languages corresponds to the basic meaning B_1, "V_1 lend V_2 a hand" and "help" to B_2, rules R_9 and R'_1 correspond to meaning rule M_1, R_2 and R'_2 to M_2, R_5 and R'_4 to M_4, etc..

In this way it is possible to establish a correspondence between complex basic expressions in one language and basic expressions that are not complex in another. In a similar fashion it is possible to establish a relation between complex basic expressions in one language and complex basic expressions in another. Note that in this way it is not necessary to incorporate a so-called structural transfer in the machine translation system for the translation of CBE's.

3.2 Other Reasons for Having Complex Basic Expressions

Expressions that are not idiomatic, but that consist of more than one word can be handled by means of a complex basic expression in order to retain the isomorphy. This is the case if the expression (i) corresponds to an idiom or (ii) corresponds to a word in another language. Examples are the following:
(i) In Dutch (37) is not an idiom in the sense defined above (i.e. the meaning of the expression "kwaad worden" can be composed in a natural way from "kwaad" and "worden"), but has an idiomatic equivalent in English (38).

(37) kwaad worden (Eng. "become angry")
(38) lose one's temper

If "kwaad worden" has to correspond to "lose one's temper", then in a technical sense, in Dutch, "kwaad worden" can be treated in the same way as an idiom.

(ii) The Italian word (39) which translates into English (40) and Spanish (41) which translates into English (42) are words that correspond to complex expressions in English (and Dutch). From a translational point of view cases like "get up early" can be treated in the same way as idioms.

(39) adagiare
(40) lay down with care
(41) madrugar
(42) get up early

4 Some Typical Problems

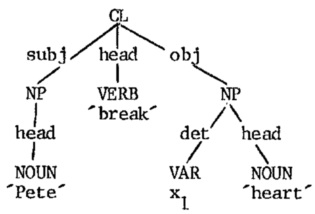
In this section some of the problems mentioned in the introduction will be briefly discussed.

4.1 Argument Variables Embedded in a Complex Basic Expression

In sentence (43) there are two arguments "Pete" and "Mary" and the idiom "x_1 break x_2's heart". The subject ("Pete") is treated in the same way as in the previous examples. The argument substitution rule substitutes the variable by the NP "Pete", giving the structure in (44), in which, eventually, the NP "Mary" substitutes for the argument variable x_1. Special M-Rules will have to be added to an M-grammar to achieve this kind of substitution. 'Normal' argument substitution rules substitute for the variables in their canonical positions, i.e. as a subject or (indirect) object directly under the clause node or as an object to a preposition in a prepositional object.

(43) Pete <u>broke</u> Mary's <u>heart</u>

(44)



The argument substitution rule for this type of construct looks like the following:

$R_{10,h}$: if t_1 is of category NP and
t_2 is of the form CL[mu1, NP[det/VAR(x_h), mu2], mu3]
then: CL[mu1, NP[det/t1, mu2], mu3]

In this rule t1 is assigned genitive case.

Rule $R_{10,h}$ applied to NP(Mary) results in CL(Pete break Mary's heart).

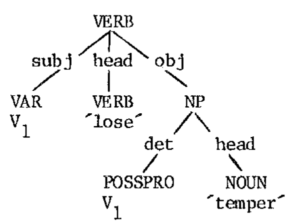
In this way it is also possible to deal with the constructs mentioned in the introduction, as for example "x_1 ran x_2 down x_3's throat".

4.2 Variables Bound by Arguments

Sentence (45) contains a possessive pronoun "his", that refers to the subject "the boy". In the lexicon the basic expression is represented as in (46).

(45) the boy <u>lost</u> his <u>temper</u>

(46)



The M-Rule that inserts the CBE makes all possible forms of the possessive pronoun (his, her, their, etc.). The substitution rule for the subject decides upon the form of the possessive pronoun.

In (47) the possessive pronoun "her" is bound to the object "the woman". The treatment here is similar to the one above. The argument to which the pronoun has to be bound is indicated in the lexicon.

(47) the man <u>gave</u> the woman her <u>freedom</u>

5 Conclusion

The method described in this paper for the treatment of idioms can deal with the problems traditionally related to expressions of this type. Structural transfer is not necessary, since idioms are mapped onto basic meanings. The grammar can operate on idiom structures in the same way as it operates on non-idiomatic structures, while, in the case of certain idioms, restrictions on operations are specified. A test implementation in the Rosetta machine translation system has shown that this approach is promising.

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Notes

(1) Different native speakers of a language may vary in their judgements about the possible transformations an idiom may undergo. Though this poses a problem, it will be ignored for the present.

(2) This paper deals only with idioms with a verb as head. Idioms of the type "spic and span" and "at any rate" are 'fixed', i.e. they cannot undergo any syntactic transformations. They are therefore less interesting from a theoretical point of view. In Rosetta fixed idioms will be treated as one word in the morphological component.

(3) Basic S-trees are similar to the Montague grammar concept of basic expressions. The term basic expression will be used frequently to indicate both.

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