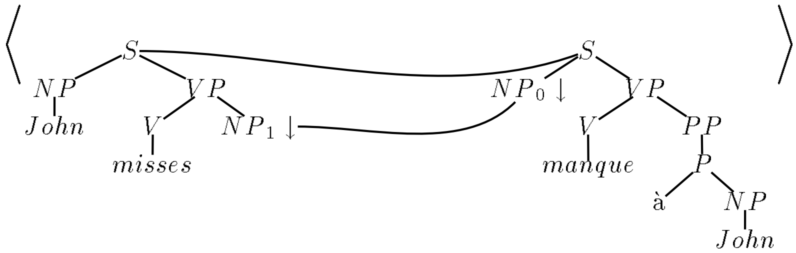
1 Synchronous Tree Adjoining Grammars

Synchronous TAGs are a variant of TAGs introduced by [Sheiber and Schabes, 1990] to characterize correspondences between tree adjoining languages. They can be used for relating TAGs for two different languages for the purpose of machine translation [Abeille *et al.*, 1990], or for relating a syntactic TAG and a semantic one for the same language [Sheiber and Schabes, 1990, Abeille, 1992] for the purpose of generation [Sheiber and Schabes, 1991] or semantic analysis.

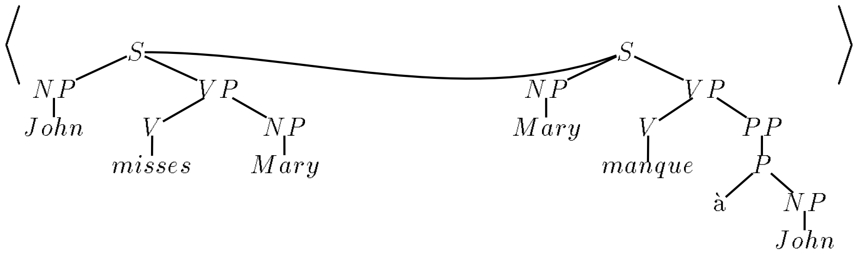
For example, consider the synchronous transfer between grammars of English and French. Although the approach is not directional, call English the source and French the target language. The transfer lexicon puts into correspondence a tree from the source grammar instantiated by lexical insertion (all its nodes and their attributes) with a tree from a target grammar. First the source sentence is parsed according to the source grammar. Each elementary tree in the source derivation tree is then mapped to a tree in the target derivation tree by looking in the transfer lexicon. The target sentence is then read off the target derivation tree.

Consider the fragment of the transfer lexicon given in Figure 1.

The transfer lexicon consists of pairs of trees one from the source language and one from the target language. Within the pairs of trees, nodes are linked. Adjunction or substitution is generalized from occuring on one node in a tree to pairs of nodes in tree pairs which are linked together. Suppose we start with the pair ψ and we operate the pair α on the link from the English node NP_0 to the French node NP_1. This operation yields the derived pair α_1.

α_1


Then, if the pair β operates on the NP_1-NP_0 in α_1, the following pair α_2 is generated.

α_2


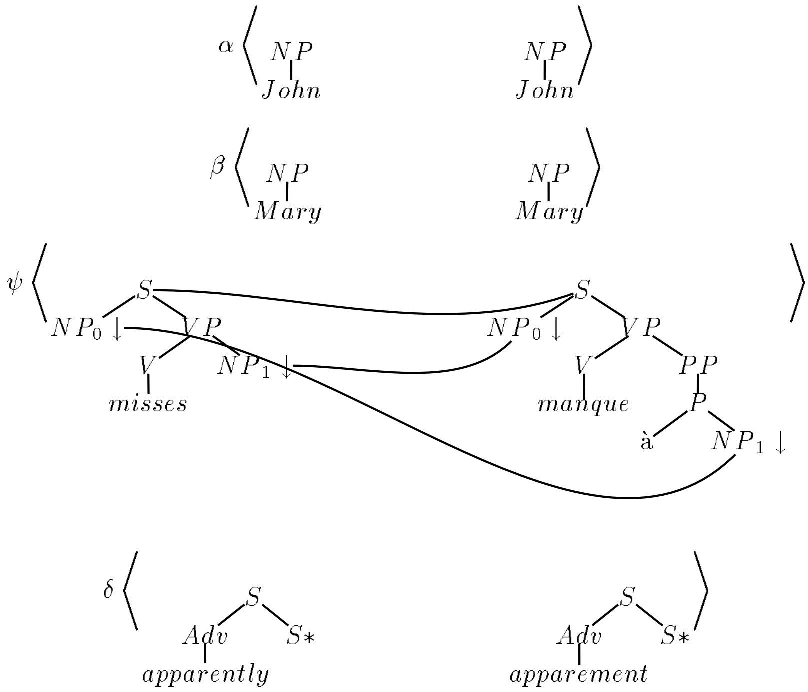
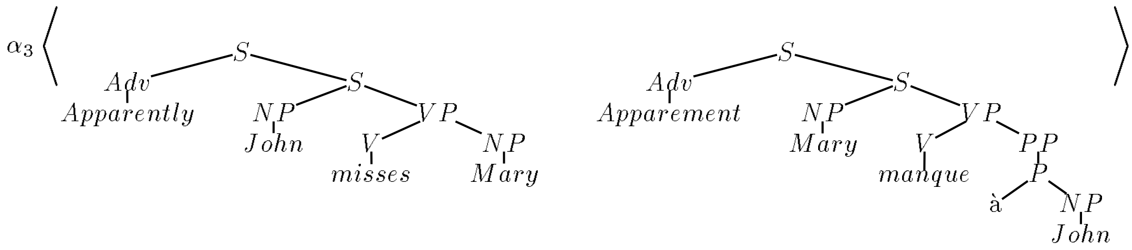


Figure 1: Fragment of the English-French transfer lexicon

Finally, when the pair δ operates on the S-S link in α_2, the pair α_3 is generated.



The fragment of the transfer lexicon given in Figure 1 therefore enables us to translate `Apparently, John misses Mary` to *Apparement, Mary manque à John*.

1.1 Why Synchronous TAGs?

The arguments for factoring recursion and dependencies as TAGs do for the syntax of natural language have their counterparts in the synchronous TAG formalism as in this case we have pairs of elementary trees each of which satisfies these properties. The structure of TAGs allows syntactic dependencies—agreement, subcategorization, and so forth—to be localized in the primitives of the grammar, the elementary trees. This is also true for long-distance dependencies such as wh-phrases. Transfer rules are stated as correspondences between nodes of the elementary trees of a TAG associated with lexical entries. We can thus define lexical transfer rules over a large domain of locality.

1.2 The Formalism

A synchronous TAG G is given as a set of triples $\{\langle L_i, R_i, \frown_i\rangle\}$, where the L_i and R_i are elementary trees, both initial and auxiliary, forming two component TAGs $G_L = \{L_i\}$ and $G_R = \{R_i\}$, and $\frown_i$ is the linking relation between tree addresses in L_i and R_i. Such a grammar is intended to define the language of pairs $L(G) = \{\langle l_i, r_i\rangle\}$. x_L and x_R denote the left and right components of x, and this notion is generalized to denote the first and second components of a triple.

The rewriting process proceeds by choosing an initial tree pair $\langle I_L, I_R, \frown\rangle$ to be the *current derived tree pair* and repeatedly performing the following steps:

1. Choose a link $t_L \frown t_R$ between two nodes in the current derived tree pair.

2. Choose an auxiliary tree pair $\langle A_L, A_R, \frown'\rangle$ from the grammar such that A_L can adjoin at t_L in I_L and A_R can adjoin at t_R in I_R.

3. Modify the current derived tree pair by adjoining the chosen trees at the end of the chosen link, yielding the modified derived tree pair $\langle I_L[A_L/t_L],\ I_R[A_R, t_R], \frown''\rangle$. This becomes the new current derived tree.

The operation $I[A/t]$ used above takes a tree I, an auxiliary tree A, and an address t in I and yields the result of adjoining A at address t in I. This operation can also refer to substitution without loss of generality. The definition of the link relation in the derived tree pair $\frown''$ is as follows: All links in $\frown$ and $\frown'$ are included in $\frown''$ (after suitable readdressing) except that the chosen link in $\frown$ is not itself included in $\frown''$. Other links that impinge on the nodes at the end of the chosen link are retained in the derived tree pair.

2 Current Implementation

This is a brief overview of the features of the synchronous Tree Adjoining Grammar (TAG) transfer module that is available as an extension to the XTAG system [Prigent, 1992]. This module can be used to transfer derivation trees generated by some source TAG to derivation trees in some target TAG. It uses a specification of transfer between the source and target TAGs.

2.1 Correspondences

The basic idea of the transfer module is to rely on derivation trees to transfer from one language to another. Given a derivation tree, from parsing a sentence in the source language, the target derivation tree will be built by a node to node correspondence in the derivation tree, i.e. an elementary tree to elementary tree correspondence, preserving the dominance relation between nodes in the derivation tree.

The following correspondences have to be defined for a TAG transfer to take place:

Node to node correspondence This is the mapping between the nodes in the elementary trees of the two TAGs. The node to node correspondence defined for each elementary tree pair completely defines the target derivation tree given a source derivation tree. As we use a Lexicalized TAG paradigm, from the lexical point of view, the elementary tree to elementary tree correspondence is in fact a lexicalized tree to lexicalized tree correspondence.

Lexical Entries The lexical correspondence is defined in terms of what is called a lexical entry. For transfer purposes, a lexical entry is close to a semantic entry (the sense of a word), not a syntactic or morphological class. This information is transferred using the next transfer technique.

Feature transfer The transfer of feature structures associated with the trees is restricted to the morphological features. Structural or syntactic features are not transferred, but are in fact transferred implicitly within each tree transfer. This feature transfer is defined from head to head in each lexicalized tree pair, be they purely local to the morphological head or inherited by the head during the feature propagation process.

2.2 Examples

The following are examples of the transfers which illustrate the cases of synchronous mapping defined above.

```
1. Jean aime Marie

===> John loves Mary


2. The farmer gives apples to John

===> le fermier donne des pommes ‘a Jean
```

```
===> le fermier donnera des pommes ‘a Jean
                    ; ‘gives’ ambiguous between present and future tense

3. le fermier qui aime Jean aime Marie

===> the farmer who loves John loves Mary
```

2.3 Complex Transfers

The transfer operation described above, based on one-to-one elementary tree correspondence, has been extended to handle cases where simple paradigm is insufficient:

- Translation of a single word to a (non idiomatic) expression (authoress → *femme ecrivain*, *boulangere* → baker's wife),
- Translation of some syntactic particularities (the sun melts the snow → *le soleil fait fondre la neige*),
- Others: hopefully → *on espere que*.

In all these examples, the correspondence is not between two elementary trees, but between an elementary tree and a (partial) derivation tree. The transfer paradigm has been extended to deal with these kind of transfers.

This kind of transfer is restricted in the actual implementation to derivations where the sons are all completely specified, i.e. they are lexicalized trees. The only lexical entry that can be left unspecified, is the lexical entry of the root of the partial derivation. This allows the use of complex transfer specifications for generic tree or family transfers (examples like "melt/*fondre*", see data transfer examples below). Recently, the formal consequence of such rules under synchronous TAGs have been studied, see Section 3.3.

2.4 Examples

```
4. la belle fermi‘ere donne une pomme ‘a Jean

===> the farmer ’s beautiful wife gives John an apple
===> the farmer ’s beautiful wife gives an apple to John


5. la neige vient de fondre

===> the snow just melted
```

```
===> the snow just melts


6. le soleil vient de faire fondre la neige

===> the sun just melted the snow
===> the sun just melts the snow


7. on esp‘ere que la fermi‘ere aime le fermier

===> hopefully the farmer ’s wife loves the farmer


8. hopefully John loves Mary

===> on esp‘ere que Jean aime Marie
```

With this extension, the feature transfer process has been extended to feature transfer between any heads in the derivation. In the "melt/*faire fondre*" example, the mode and tense features are transfered between "melt" and "*faire*" instead of between "melt" and "*fondre*".

3 Making stag easier to use

3.1 Morphological Generation

Within the paradigm of the transfer of morphological features The target features (i.e. the features transferred from the source head features) do not provide absolute specifications for the morphological head in the target language. They are considered as indications to find the best words during morphological generation, but can be cancelled by other constraints in the target language. The morphological generation phase is therefore an optimization process: given the structural constraints and the proposed transfered features, find the morphological words that satisfy the maximum number of proposed features. (This optimization should be a global optimization, but is currently implemented as a local optimization, which can have global consequences due to feature propagation).

An example of this is:

```
9. the farmer ’s wife loves Mary
```

```
===> (D) femme de le fermier aime Marie
===> la fermi'ere aime Marie
```

3.2 Extension to Tree/Feature Transfer

Another extension that is useful is to allow tree to feature transfer. Some aspects of one language may have different forms in a different language. For example one language can use a morphological derivation to express some aspect while another language uses a syntactic derivation to express the same aspect. An example between French and English is the future tense: an auxiliary verb is used in English and morphological derivation in French.

3.3 Natural Definition of synchronous derivation

A recent paper [Sheiber, 1993] defines formally the notion of a synchronous derivation in terms of a pair $\langle D_L, D_R \rangle$ where D_L, D_R are well formed derivation trees and which are isomorphic to each other with respect to dominance, and in which the links in the tree pairs obey this isomorphism. Under this treatment, the kind of transfers effected in Section 2.3 can be principled to generate only the set of Tree Adjoining Languages, but the isomorphism requirement may rule out certain transfers needed in a synchronous transfer system. But it seems that different kinds of nonisomorphic mappings can be tailored to various applications, even though a proper solution to this problem is still open.

References

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