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A Minimal Transfer Conception for Verbmobil

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Gehört zum Antragsabschnitt: 12.4 Kontextuelle Constraints
12.6 Äquivalentwahl

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Abstract

In this paper we introduce the transfer conception MinT that is currently being developed for the prototype of the face-to-face translation system VERBMOBIL.[1] The acronym MinT stands for Minimal Transfer. MinT is a semantic-oriented transfer model that is based on some central ideas of the MRS-based approach outlined in [Copestake et al., 1995], and the Shake-and-Bake approach to machine translation sketched in [Whitelock, 1992]. The central idea of minimal transfer is to relate the source and target language semantic descriptions on a maximal abstract level, without falling back into the well-known problems of the Interlingua approach. Minimal transfer results in simultaneously decreasing the number of transfer rules and leaving a maximal set of options for lexicalization and grammaticalization up to the generator.

In sum, MinT can be characterized as a semantic-oriented, unification-based and lexicalist transfer model. Its main knowledge base are transfer statements which provide the correspondences between underspecified semantic predicates of the source and target language. Transfer statements comprise both bilingual and monolingual correspondences. Bilingual correspondences, on the one hand, establish the equivalence between sets of semantic predicates of the source and target languages. They are formulated in a strictly declarative way and can be applied bidirectionally. In order to solve translational ambiguities, the roles and instances of a predicate are typed with fine-grained sorts that are supplied by an elaborated sort hierarchy. Monolingual correspondences, on the other hand, provide a solution to divergences in the logical structure of the languages involved. The idea is to allow the transfer component to initiate further compositional processes if this is motivated by the contrastive situation. Thus, the input structure is transformed into a logically equivalent semantic representation that is shared by the target language. This way, all contrastive knowledge is contained in the transfer component, which allows strict modularity of analysis and generation.

[1] A brief introduction into the MinT conception is given in [Abb and Buschbeck-Wolf, 1995].

Contents

1 Introduction

In this paper we present the transfer conception of MinT that is currently being developed for the prototype of the face-to-face translation system VERBMOBIL.[2] The acronym MinT stands for Minimal Transfer, because the central idea of our model is to relate the source language (SL) and target language (TL) semantic descriptions on a maximal abstract level, such that the transfer efforts can be reduced significantly.[3]

With the MinT approach we try to avoid various disadvantages well-known both from transfer and Interlingua (IL) approaches. Let us take a closer look at the difficulties of these approaches.

The IL approach assumes that all languages map onto a single abstract representation. This assumption is lucrative, since the addition of a new language to an IL system only requires the addition of a new analysis and a new generation component, but no further transfer modules for the new language pairs have to be developed.[4] Moreover, the IL idea leads one to expect that analysis and generation are independent of the languages involved, i.e. strictly modular. Although there is a set of universal concepts that proved to be useful in contrastive lexical semantics, the idea that translations always share the same IL representation is unrealistic because of *translation divergences*, i.e. cases where two languages do not share the same logical structure, cf. [Dorr, 1993], and *translation mismatches*, i.e. cases where the languages involved cannot be mapped onto a single conceptual representation, cf. [Kameyama et al., 1991] and [Kay et al., 1991]. If we, nonetheless, want to find an IL representation, then it has to be as specific as required by all languages involved. Consequently, the analysis is fine-tuned w.r.t. possible TLs, and the language independence assumption is at risk.

In contrast to the IL strategy, **the transfer approach** relates SL lexical items and grammatical structures directly to their TL correspondences. This results in the fact that the addition of a new language to a transfer system with n languages requires the addition of n∗(n-1) new transfer modules, cf. [Hutchins and Somers, 1992].

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[2] We want to express our gratitude to Megumi Kameyama and Anke Lüdeling for most valuable comments on this topic.

[3] For the time being, MinT is for the most part a theoretical specification. Implementation is still work in progress.

[4] This topic is relevant for the VERBMOBIL prototype because the transfer component has to mediate between German, English and Japanese.

Depending on the level of linguistic information on which the transfer is carried out, the sets of rules might become very complex. The more abstract the level of representation the more compact the transfer might be. Especially syntactic transfer systems tend to restate the entire source grammar in their rule system, cf. [Kay et al., 1991].[5] To ensure compatibility, the rules must be written with both monolingual grammars in mind, which implies that declarativity and bidirectionality are difficult to achieve.

One way to cope with the difficulties mentioned above is a **transfer at an abstract semantic level** that garantees modularity of SL and TL grammars. If we make extensive use of underspecification and abstraction, the transfer rule system can be reduced to a minimum so that the costs of the involvement of new languages becomes justifiable. In addition, this method has the advantage that lexical correspondences can be established directly. This way, problems of defining an IL concept for cases of translation mismatches can be circumvented by the specification of mapping rules (cf. 5.2).

There is a further difficulty for semantic transfer models: the problem of logical form (LF) equivalence (cf. [Landsbergen, 1987], [Whitelock, 1992], [Copestake et al., 1995]). In short, logically equivalent LF may differ across languages with respect to their bracketing. Thus, the generator might get a SL input structure that is well-formed w.r.t. to the principles of LFs but which is not acceptable in the TL.

One solution to this problem is the Shake-and-Bake approach ([Whitelock, 1992], [Beaven, 1992]). Whitelock and Beaven have shown that the generation from an LF can be constrained if the transfer is restricted to pure coindexation of SL and TL lexical signs. This has the advantage of modularity since no information of the monolingual grammars is involved, but also the disadvantage that complex equivalences, which involve more than one lexical item, are difficult to express.

The Quasi-logical form (QLF) transfer, cf. [Alshawi et al., 1991], provides another solution to this problem. Here, the transfer produces only semantic representations that are syntactically and semantically equivalent to a QLF accepted by the generator.

Based on the QLF transfer and the Shake-and-Bake translation approach, [Copestake et al., 1995] propose a third solution to the problem of LF equivalence, using minimal recursion semantics (MRS). The basic idea is to represent semantics in a flat list of predicates that are chained up via coindexation of special attributes, called *handels*, see section 3.

[5]This property is often called the built-in redundancy problem, cf. [Isabelle et al., 1986].

The MinT conception is based on some central ideas of the MRS-based transfer outlined in [Copestake et al., 1995]. It is a semantic-oriented, unification-based and lexicalist transfer model. But, it differs from the latter in certain points. In MinT, the idea of *abstraction and underspecification* is worked out in much more detail and has been applied to a variety of translational phenomena. In addition, the rule system has been extended to cope with structural-semantic divergences and mismatches in a systematic way.
At this point, we like to sketch the main features of MinT. It is based on a version of MRS being developed at IBM, cf. [Egg and Lebeth, 1995]. As has been mentioned, the use of underspecified representations and the recourse to abstract predicates minimize the transfer descriptions. Ambiguities holding across the languages involved are preserved as far as possible in order to avoid expensive resolution procedures. Moreover, the specific grammaticalization and lexicalization are left to the generation component.
The main knowledge base of MinT consists of *transfer correspondences* (TC). In general, TCs define the mappings between bilingual or monolingual sets of semantic predicates.
Bilingual correspondences establish the equivalence between SL and TL semantic predicates. They are formulated in a strictly declarative way and can be applied bidirectionally. For the resolution of translational ambiguities we use sortal restrictions. In order to serve the different kinds of translational phenomena, we have defined a system of correspondence rules, cf. 4.3.1, that provides different translation techniques for different phenomena. They range from interlingual to idiosyncratic rules.
Monolingual correspondences provide a solution to structural divergences in the logical structure of the SL and TL, cf. [Dorr, 1993]. They rearrange the SL semantic structure by decomposition or recomposition. We assume a two-level approach of semantic composition: an initial composition is carried out in the semantic analysis where semantic structures are kept as compact as possible, respecting the requirements of a reasonable semantic representation. Transfer then may initiate further composition steps if this is motivated by the contrastive situation. In such cases, the semantic structure of the SL is decomposed or recomposed into an equivalent logical structure that provides the right starting point for the application of standard bilingual correspondences.

After some introductory remarks on the underlying ideas of MinT, we outline, in section two, its embedding in a architecture of a speech-to-speech translation system. Section three describes the semantic representation that forms the input to the transfer module. In the fourth section, we represent the knowledge bases of

MinT: the relation hierarchy, the sort hierarchy and the system of transfer correspondences. Finally, we illustrate, in section five, how MinT resolves well-known types of translation mismatches and divergences in a lexically-guided manner, applying the introduced types of rules.

2 The Architectural Environment of MinT

In this section, we will first outline how the MinT module is integrated into the architecture of a speech-to-speech system. Next, we will describe some pecularities of the VERBMOBIL architecture.

2.1 MinT and the Architecture of a Speech-to-Speech Translation System

Figure 1 sketches how MinT fits into the picture of the architecture for a speech-to-speech translation system. According to this picture, MinT communicates at least with semantic analysis, semantic evaluation and generation.

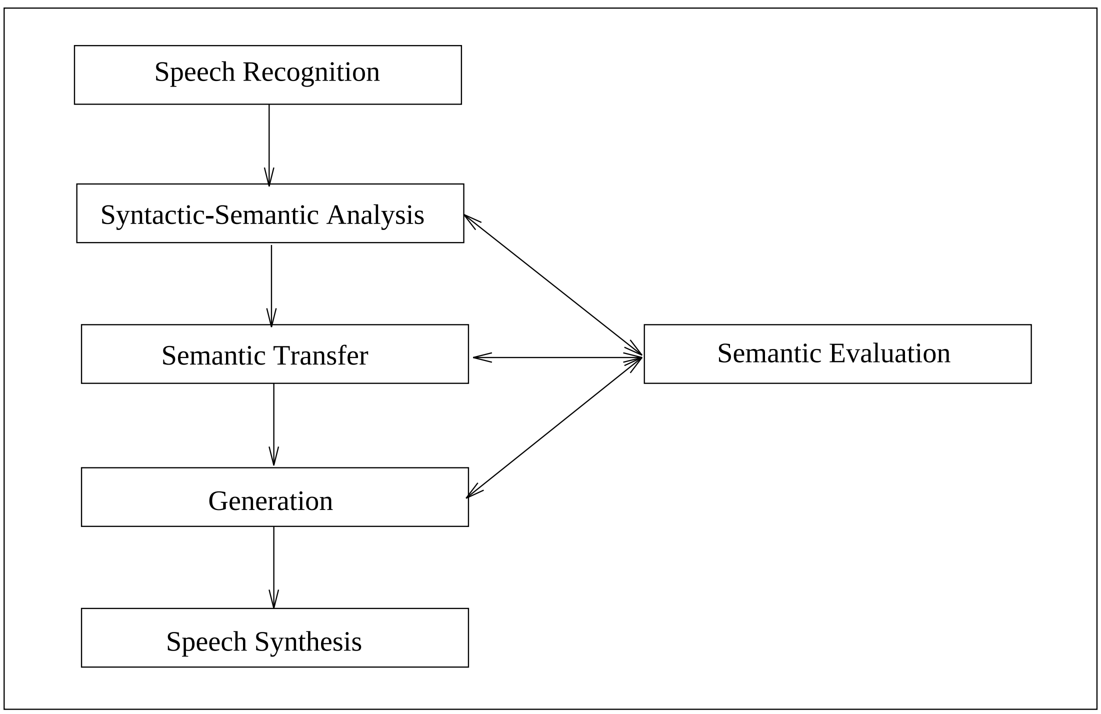

Figure 1: The architecture from the viewpoint of the transfer component

For the time being MinT is designed as a sentence-based transfer model. [6] The utterances to be interpreted are recognized by a speech recognizer and are syntactically and semantically analyzed, then. As input to the MinT module we assume MRS structures, cf. section 3. These representations also form the semantic basis for a broader discourse representation that is produced by a semantic evaluation component. This module provides information about the dialogue context and the speech acts by integrating domain specific world knowledge. It allows the semantic analyzer, the transfer module as well as the generator to access additional knowlegde for their module specific tasks. The transfer module provides the generator with TL MRS representations which are underspecified w.r.t. grammaticalization and lexicalization. The generator maps the TL semantics on adequate lexical and grammatical expressions. The phonological output of the generator is then transformed to speech by the synthesis component.
For reasons of efficiency, we do not assume a complex interaction between transfer and its neighbouring modules. We assume a unique and valid semantic input, a one step interaction to semantic evaluation and the possibility for generation to backtrack over transfer solutions.

2.2 Some Peculiarities of the Verbmobil Architecture

The VERBMOBIL architecture displays some special features. First, there are two competing modules for the syntactic/semantic analysis. In the first one, syntactic processing (the Siemens TRUG system) precedes semantic processing, cf. [Bos et al., 1994], in a sequential way. In the alternative module developed at IBM, an integrated HPSG syntax/semantics representation is built up. Fortunately, the different interplay between syntax and semantics does not really touch the transfer module since it is semantic-oriented and does not rely on syntactic information.
Concerning the transfer input, a problem arises with the competing formalisms for lexical and compositional semantics. There are two proposals: the semantic formalisms LUD, cf. [Bos et al., 1994] and the Heidelberger MRS, cf. [Egg and Lebeth, 1995]. For the transfer component, it is important to be provided with a unique semantic representation with the same data structure. We will refer to MRS representations as data structure for the semantic input as well as for the transfer rule specification.[7]

[6] As will be discussed in section 4.3.4, the MinT system is in principle able to deal with much smaller semantic units.

[7] There is a further reason for using MRS representations as data structure in the transfer component. The English grammar and lexicon provided by the CSLI group are also encoded in MRS. To keep the cost of data conversion as small as possible, both generation and transfer

The semantic evaluation module of VERBMOBIL supports speech event recognition, context interpretation and inferencing, cf. [Quantz et al., 1994]. The transfer component consults this module if it cannot resolve translational ambiguities with the available local linguistic information. Thus, making use of additional knowledge, inferencing, and defaults, the semantic evaluation component provides a further disambiguation device.

Another competition holds between two subsequent modules: transfer and generation. Due to module internal competence, a lot of information can be processed either by the transfer module or by the generator. In contrast to most of the known MT systems, in VERBMOBIL, transfer is forced *not* to compute as much target restrictions as possible, but has to respect the competence of the subsequent generation module. This conflict is solved by minimizing the restrictions on the TL in a reasonable way. To achieve this we make an extensively use of underspecification and abstraction.

3 Minimal Recursion Semantics for Transfer

Our transfer relates a set of source MRS relations to a set of target MRS relations. In the following we will introduce the basic concepts of MRS, as it is defined in [Copestake et al., 1995] and extended and modified in [Egg and Lebeth, 1995].

Experiences from the VERBMOBIL demonstrator, cf. [Dorna et al., 1994], have shown that a highly structured semantic formalism, such as λ-DRT, cf. [Bos et al., 1994], causes unnecessarily high computational costs. MRS was developed as a semantic framework within HPSG[8] that is more suitable for the requirements of semantic transfer.

The core feature of the MRS formalism is the possibility to underspecify semantic ambiguities such as the scope of quantifiers or the attachment of modifiers in a feature structure. MRS also represents semantic structures as flat as possible without losing the power to represent semantic structuring.[9]

The representation in (1) shows the MRS feature structure for the expression *der lange Samstag* (literally: "the long Saturday", a Saturday on which the shops are open longer than on other Saturdays). It consists of a feature HANDEL for handling semantic embedding (value: constant), a feature INST representing the referential or external argument (value: type of the sort hierarchy),

operate best on MRS representations.

[8]cf. [Pollard and Sag, 1987] and [Pollard and Sag, 1994]

[9]In other words: the notions of "flat representation" or "minimal recursion" indicate a semantic representation which combines the computational advantage of a flat data structure (here: a list) with the theoretical issues of modelling semantic dependencies.

and a list of relations (value: type of the relation hierarchy). With recourse to [Pollard and Sag, 1994], semantic predicates are represented as types of relations embedded in a type hierarchy that introduces features for sorted instances and roles.

(1)
$$\begin{bmatrix} \text{HANDEL} & \text{h1} \\ \text{INST1} & \fbox{1}\ \textit{entity\_s} \\ \text{LISZT} & \left\langle \begin{bmatrix} \textit{samstag\_rel} & \\ \text{HANDEL} & \fbox{2}\ \text{h1} \\ \text{INST} & \fbox{1}\ \textit{tag\_s} \end{bmatrix}, \begin{bmatrix} \textit{lang\_rel} & \\ \text{HANDEL} & \fbox{2} \\ \text{INST} & \fbox{1} \end{bmatrix}, \begin{bmatrix} \textit{def\_rel} & \\ \text{HANDEL} & \text{h2} \\ \text{BV} & \fbox{1} \\ \text{RESTR} & \fbox{2} \end{bmatrix} \right\rangle \end{bmatrix}$$

The core element transfer refers to is the value of LISZT, a flat list of types introduced by the type hierarchy of relations. Logically, the value of LISZT represents a set-valued conjunction of predicates. In our view to grammar, every lemma[10] is associated with at least one relation. As a consequence, we get a very close connection between the predicates' type names and the words in the lexicon. Semantic relations are combined during the semantic composition by functional application or functional composition.

All relations have a HANDEL feature. Handels serve to address relations and are combined to a (partial) chain in two possible ways: In a functor argument relation, the argument's handel is embedded via the feature HD_ARG in the functor's representation. In the case of intersective modification, the handels and also the instances of the modifier relations are unified. Non-intersective modification is treated as a special case of a functor argument relation. For example, an intensifier refers to the handel of its argument via HD_ARG, and identifies its degree argument (feature: DEGREE, value: scalar unit), but not its instance, with that of its modified element.

Following [Barwise and Cooper, 1981], determiners are represented as general quantifiers. A generalized quantifier exhibits a bounded variable (BV), a quantifier restriction (RESTR) and a scope (BODY). In MRS, BODY is introduced by a specific subtype and can be left out in order to represent underspecified scope, cf. [Copestake et al., 1995].

Underspecification of semantic embedding is modelled by means of so-called *handel lists*. The handel list of a semantic functor contains all possible handel/instance pairs which might be in its scope, respecting such constraints as irreflexibility (a functor cannot refer to itself) or antisymmetry (e.g., a functor can-

[10] Following [Kempen and Huijbers, 1983] we call the syntactic/semantic core partition of a lexical entry a *lemma* and its morpho-phonological forms *lexemes*.

not take as its argument a functor that again takes as its argument the embedding functor). For a more detailled discussion of this topic, see [Egg and Lebeth, 1995]. The MRS in (2) examplifies the semantics of a verb. It represents a partial MRS for *Peter trifft Maria* (Peter meets Maria).

(2)
$$\left[\begin{array}{ll} \text{HANDEL} & \mathsf{h1} \\ \text{INST1} & \boxed{1}\ \textit{entity\_s} \\ \text{LISZT} & \left\langle \left[\begin{array}{ll} \textit{treffen\_rel} & \\ \text{HANDEL} & \text{h1} \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{array}\right], \left[\begin{array}{ll} \textit{maria\_rel} & \\ \text{HANDEL} & \text{h2} \\ \text{INST} & \boxed{2} \end{array}\right], \left[\begin{array}{ll} \textit{peter\_rel} & \\ \text{HANDEL} & \text{h3} \\ \text{INST} & \boxed{3} \end{array}\right] \right\rangle \end{array}\right]$$

Note that we assume a very straightforward naming of roles. From the viewpoint of transfer, a fine-grained differentiation of role names is neither necessary nor desirable. We do not subscribe our approach to any specific role theory but prefer a minimal role system, like e.g. the proto role approach of [Dowty, 1991] or [Davis, 1995]. In the first run, we adopt the simplest form of naming roles by calling them ARG1, ARG2, etc. As a convention, we use ARG1 for agent-like arguments, ARG2 for experiencer-like arguments, and ARG3 for theme-like arguments.

Let us close this subsection with some final remarks: It is important to know that the MRS version developped at IBM is interpretable w.r.t. the predicate calculus; cf. [Egg and Lebeth, 1995]. Furthermore, it is convenient to have SL and TL semantic representations that are based on MRS. It would be most favourable to integrate the language-specific relations into a unique hierarchy. Otherwise, as far as underspecified relations are concerned, one has to guarantee at least local compatibility of the different relation hierarchies. Moreover, it would be best to make use of a common sort hierarchy. Alternatively, in a system with different sort hierarchies one has to make the language-specific hierarchies compatible. This can be controlled by an artificial super sort hierarchy that is defined as the union of the language-specific sort hierarchies. In sum, the usage of the same knowledge bases is a highly desirable system feature that bears the advantage of a compact, efficient, and consistent processing. However, we are not sure that this can be realized in such a huge project as VERBMOBIL.

4 The Transfer Knowledge Bases of MinT

In this section we describe the knowledge bases of MinT. These include the source and target language specific relation hierarchies, a language-independent sort hierarchy, and a system of transfer correspondences.

4.1 The Hierarchy of Semantic Relations

As has been noted in section 3, semantic predicates are modelled as types according to a type hierarchy of semantic relations. The internal structure of this hierarchy is motivated by both semantic analysis and transfer.

Semantic analysis needs a minimal inventory for classifying different semantic types to build up different semantic representations. As sketched in section 3, types serve to model the different semantic properties of, e.g., nominals vs. verbals or operators vs. non-operators, and to establish underspecified semantic relations between functors and their possible arguments. Moreover, the model of linking between syntax and semantics is anchored in the type definitions. It provides a classification of verbs where, e.g., information about argument structure and aspectual properties, can easily be identified.

The idea of minimal transfer is based on the concept of underspecification that requires the definition of abstract predicate classes. These classes are modelled by integrating less specific types in the semantic hierarchy that correspond to bundles of lexical predicates. The transfer specifications operate on these abstract types whenever this is admissible. Note that the definitions of these bundles must be formulated in a general way such that no violation of the modularity constraint between the monolingual and bilingual knowledge bases occurs.

The signature in (3) shows a commented partition of the recent semantic relation hierarchy developed at IBM. We use CUF, cf. [Dörre et al., 1994], as a type description language. The type system is characterized by multiple inheritance, type axioms with the power of propositional logic, and appropriateness of features. The types that represent semantic relations are identified by the extension "_rel".[11]

[11] The symbol "=" specifies the relation between a type and its subtypes. Disjointness and exhaustivity are expressed by the symbol "|", and disjunctive types by ";". The symbol "::" indicates the introduction of the features appropriate for a type, and ":" specifies which type is appropriate for the introduced feature.

(3)

```
% A semantic entity is either a MRS structure consisting of a list of
% relations and an instance, or it is a semantic relation.

  cont = mrs | relation.
  cont :: HANDEL: handel.

  mrs :: LISZT: dlist,       % dlist    = difference list
         INST1: entity_s.    % entity_s = top of sort hierarchy

% RELATIONS
% - are cross classified w.r.t. their basic relation types and their
%   referential properties (referential relations bear an INST feature)
% - introduce a list of handel/instance pairs whose members function
%   as values of HD_ARG and/or INST in unambigous cases

  relation = eventuality_rel | nom_rel | degree_rel | prep_rel
           | quant_rel | coordination_rel | ...
  relation = non_ref_relation | ref_relation.
  relation :: POSS_PAIRS: dlist.

  non_ref_relation = quant_rel | coord_rel | ...

  ref_relation = eventuality_rel | prep_rel | nom_rel | degree_rel.
  ref_relation :: INST: entity_s.

% QUANTIFYING RELATIONS
% - introduce a bounded variable and a quantificational restriction
% - do not specify a body for its scope domain for the moment

  quant_rel = w_def_rel | def_rel | indef_rel | forall_rel | ...
  quant_rel :: BV :   entity_s,
               RESTR: thing.

 % COORDINATION RELATIONS
 % - introduce two features for their conjuncts

  coord_rel = or_rel | aber_rel | ...
  coord_rel :: CONJ1 :  handel,
               CONJ2 :  handel.

 % NOMINAL RELATIONS
 % - are subdivided into adjectival and nominal relations
 % - bear an index for agreement features

  nom_rel = noun_rel | adj_rel.
  nom_rel :: NOM_INDEX: nom_index.
```

```
% NOUN RELATIONS
% - are subdivided into relational and non-relational nouns
%   (relational nouns may introduce nominal arguments)

 noun_rel = rel_noun_rel | non_rel_noun_rel.

 non_rel_noun_rel = zahnarzt_rel | termin_rel | ...

 rel_noun_rel = chef_rel | anfang_rel | ..

% ADJECTIVAL RELATIONS
% - are subdivided into intersective and non-intersective adjectives
% - introduce a degree argument with different scale values
% - non-intersective adjectives refer to an external handel in HD_ARG

 adj_rel = intersec_adj_rel | non_intersec_adj_rel.
 adj_rel :: DEG_ARG: scale_s.

 non_intersec_adj_rel ::       HD_ARG: handel.

% PREPOSITIONAL RELATIONS
% - are cross-classified w.r.t. its basic abstract meaning, its
%   directional vs. static use and its abstract conceptual meaning
% - introduce an internal argument which may be contextually bound in
%   the case of intransitive prepositons

 prep_rel = in_rel | an_rel | ...
 prep_rel = dir_rel | nondir_rel.
 prep_rel = loc_rel | temp_rel | mod_rel | instr_rel | ...
 prep_rel :: ARG3: entity_s.

% EVENTUALITIES
% - are subdivided into scope bearing relations, functional
%   eventualities, situation pronouns, intersective adverbials and all
%   other situations

 eventuality_rel = scope_bearing_rel | func_event_rel | sit_pron_rel
                 | intersec_adv_rel | sit_rel.

% SCOPE BEARING RELATIONS
% - break down into non-intersective adverbials and modal verbs
% - take a handel as argument via HD-ARG

 scope_bearing_rel = non_intersec_adv_rel | modal_rel.
 scope_bearing_rel :: HD_ARG: handel.

 non_intersec_adv_rel = eigentlich_rel | noch_rel | ...
```

```
 modal_rel = koennen_rel | sollen_rel | ...

% FUNCTIONAL EVENTUALITIES
% - are subdivided into tense, sentence mood and pragmatic mood

 func_event_rel = tense_rel | sent_mood_rel | prag_mood_rel.

 tense_rel = past_rel | present_rel.

 sent_mood_rel = indicative_rel | conjunctive_rel.

 prag_mood_rel = decl_rel | interrog_rel | imperat_rel.
 prag_mood_rel :: HD_ARG:  handel.


 interrog_rel = polar_rel | wh_quest_rel.
 interrog_rel :: QUEST: top.

% INTERSECTIVE ADVERBIALS

 intersec_adverbial_rel = denn_rel | jetzt_rel | ...

% SITUATIONS

% - introduce three types of situation arguments
% - This subhierarchy shows just a part of the whole verb class
%   hierarchy which is currently under development by Kai Lebeth
%   at IBM Heidelberg.

% Situation structure
 sit_rel = complex | unary.

 sit_rel = und_prop | no_prop.

 complex = pre_phase ; middle ; post_phase.

 middle  = change | event.

 event = act_event | non_act_event.

 und_prop = relational | functional.

 relational = possessing | mental .

% Some verb classes ..

 static_verb = unary & functional.
```

```
 intergressive_verb = no_prop | act_event.

 possessing_verb  = unary & possessing.

 (...)

% Members of verb classes

 possessing_verb = haben_rel | ... .

 static_verb = fehlen_rel | ... .

 mental_state_verb = wissen_rel | denken_rel ... .

 intergressive_verb = husten_rel | nachschauen_rel ...

 (...)

% Appropriatness Conditions that define ARG1, ARG2, ARG3

 act_event ::
          ARG1: entity_s.

 und_prop ::
          ARG3: entity_s.

 relational ::
          ARG2: entity_s.
```

We do not go into the details of the hierarchy here. Instead, we will shortly discuss two examples where the introduction of abstract types is valuable to enable underspecified translation.

4.1.1 Different Word Options

A simple transfer module relates SL-specific predicates directly to TL-specific predicates.[12] It is obvious that, with this strategy, generation looses any freedom in lexical choice, which results in a restricted and monotonic translation. In the worst case, the translation is even unacceptable.

In a system with a separate generation component, the task of lexical choice is a matter of generation. The transfer has to provide the generator with reasonable restrictions for different word options. For some specific words, however,

[12] Transfer in the VERBMOBIL Demonstrator followed this simple strategy (cf. [Dorna et al., 1994]).

a specific lexicalization is forced by transfer, as in, e.g., *büro_rel/office_rel*, or *kaffee_rel/coffee_rel*.

In many cases, one can identify a variety of words that fit the meaning of a relation. The strategy proposed here rests on introducing abstract types in the relation hierarchy that bundle various relations. Since we probably have to deal with language-specific relation hierarchies in VERBMOBIL, we have to make sure that the abstract types are the same in both hierarchies. The abstraction process is gained via type inference. The incoming relation must be subsumed by the more abstract type of the transfer correspondences (TC). In other words, the TC ignores the specificity of the incoming predicate and instead transmits the abstract relation to the generator. The subtypes of this abstract type specify the range of possible lexicalizations in the source and the target languages. We demonstrate this strategy by a simple example. To verbalize that an appointment has to be scheduled, German and English offer a variety of verbs that leads us to introduce the type *abstr_schedule_rel* in the German (4) and the English relation hierarchy (5):

(4) abstr_schedule_rel = ausmachen_rel | vereinbaren_rel | abmachen_rel | ...
(5) abstr_schedule_rel = schedule_rel | arrange_rel | fix_rel | appoint_rel | ...

The corresponding bidirectional transfer rule is shown in (6).

(6)
$$\left\langle \begin{bmatrix} \textit{abstr\_schedule\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3}\ \textit{animate\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{abstr\_schedule\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

If one wants to get the same range of options within the simple transfer strategy, one has to specify for n German variants and m English variants $n * m$ transfer rules.

4.1.2 Different Morphosyntactic Options

Transfer on the semantic level poses specific requirements to the semantic analysis. It has to offer a solution for two possibly conflicting goals: On the one hand, semantic transfer needs an enriched semantic representation to accomodate the missing syntactic information. On the other hand, syntactic representation as, e.g., categorial information, should not be reflected too explicitly in semantic representation. This would diminish the feasibility to transfer semantic relations that are underspecified w.r.t. syntactic or morphosyntactic variants.

We illustrate this point by investigating different morphosyntactic options for a semantic predication. Typical instances of morphological derivations that share their descriptive content (or at least a significant part of it) with their morphological source are nominalizations derived from verbs or adjectives (cf. (7) - (8)) and adjectival participles derived from verbs (cf. 9) or nouns.

(7) veranstalten/die Veranstaltung/das Veranstalten/der Veranstalter
(to organize/the organization/the organizing/the organizer)

(8) möglich/die Möglichkeit (possible/the possibility)

(9a) der verhandelte Termin (the scheduled appointment)
(9b) die verhandelnden Partner (the scheduling partner)
(9c) der zu verhandelnde Termin (the appointment to be scheduled)

Before we go on, let us first clarify how composita, or, more generally, morphological complexes are dealt with. There are two strategies conceivable. In the one, they are decomposed in the semantic analysis and the transfer module operates on a number of semantically connected relations that represent the morphosemantic complex. An alternative way is to pass the complex to the transfer component without a preceding semantic analysis. The transfer module initiates then a decomposition of the complex in dependence on the specific contrastive situation. We want to argue for a hybrid system of semantic composition where decomposition of morphological complexes is done in the semantic analysis if this is sensible from the module-internal point of view. In addition, transfer may either continue the composition or also initiate decomposition if motivated by the contrastive situation.
Let us consider the examples in (10a) - (10c) and their translations in (11a) - (11c).[13]

(10a) Ich möchte einen Termin vorschlagen.
(10b) Ich möchte einen Terminvorschlag machen.
(10c) Ich habe da einen Vorschlag für einen Termin.

(11a) I like to suggest a date.
(11b) I like to make a suggestion for a date.
(11c) I have a suggestion for a date.

[13] We assume that composita of the type *Terminvorschlag* are decomposed in two thematically connected relations in the semantic anaylsis.

Every English utterance in (11a) - (11c) might occur as translation of any of the German utterances in (10a) - (10c). This variation demonstrates the necessity to foresee an underspecified relation that covers the meaning of *vorschlagen, Vorschlag machen* or *Vorschlag haben*.[14] In our system, this is achieved by introducing the relation *vorschlagen_rel* in the hierarchy which might have several subtypes for its morphosemantic variants. (12) shows the relevant extract of the German and English hierarchy.

(12) act_und_rel = vorschlagen_rel | ...
vorschlagen_rel = vorschlagen_v_rel | vorschlagen_n_rel.
act_und_rel = suggest_rel.
suggest_rel = suggest_v_rel | suggest_n_rel.

There are a number of differences between a verbalization and its corresponding nominalization which one should take into account. First of all, the arguments of nominalizations are mostly optional, cf. (13).

(13) *Ich möchte vorschlagen. (I like to suggest)
Ich möchte einen Vorschlag machen. (I like to make a suggestion)
Ich habe da einen Vorschlag. (I have a suggestion)

The easiest way to solve this problem is to assume that a derived element carries the same argument frame in its representation as its derivative.[15] The semantic analysis then specifies whether a specific argument slot is filled by the linguistic or extralinguistic context or not. This analysis results in a massive reduction of the number of lexical entries as well as transfer rules.

The corresponding transfer rule is then a simple mapping of *vorschlagen_rel* to *suggest_rel*, see 5.1.1.
But lexicalization might also differ in the specific semantic representation w.r.t. the semantic categories. In German, for example, nominalizations bear reference

[14]The introduction of underspecified relation types is supported by the fact that the target grammar may not provide a specific morphosyntactic counterpart for a SL-lexicalization.

[15]This analysis is supported by some work in theoretical linguistics. One can identify so-called *implicit arguments* which act as filler of thematic roles although they are not expressed overtly. Implicit arguments are found in, e.g., passive constructions, nominalizations and *able*-adjectives (cf. [Roeper, 1987]). They can be made explicit, among others, by control constructions, cf.:
(a) The ship was sunk to collect the insurance.
(b) the eating of meat to gain weight
(c) Goods are exportable to improve profits.

class information and are countable, whereas finite verbalizations bear aspect, tense, and mood information. But often this information is not important in the context and can be dispensed with. It is a task of the generation component to weigh a lexicalization option against the loss of information.

4.2 The Hierarchy of Semantic Sorts

The sort hierarchy represents sortal information which is frequently used in the semantic and transfer components. The sortal specification that is assigned to instances and roles of semantic relations supports the verification of semantic selectional restrictions as well as transfer-relevant disambiguation. While semantic occurrence restrictions are mostly expressed by the use of upper-level sorts, transfer often requires fine-grained sorts. This has the consequence that a type hierarchy used for disambiguation in a MT system cannot be regarded as a general epistemic ontology as in knowledge engineering. Only its upper parts reflect general ontological categories while lower-level sorts are grouped and fine-tuned w.r.t. the solution of translational ambiguities. (14) shows a part of the actual sort hierarchy where some of the criteria for cross classification of material things are introduced. Sorts are identified by the extension "_s".

(14)

```
material_entity_s   = artefact_s  |      % criterion: artificiality
                      nat_kind_s.

material_entity_s   = movable_s |        % criterion: movability
                      non-moveable_s.

movable_s           = self_movable_s |   % criterion: origin of
                      nonself_movable_s. % movability

material_entity_s   = two_dim_s |        % criterion: dimensionality
                      three_dim_s.

material_entity_s   = bounded_s |        % criterion: boundedness
                      unbounded_s.

bounded_s           = sharp_shaped_s |   % bounded things w.r.t. their
                      complex_shaped_s.  % outline

material_entity_s   = axis_obj_s |       % criterion: primary
                      non_axis_s.        % discrimination of axes
```

First of all, the sort hierarchy covers the information necessary for the disambiguation phenomena occurring in the VERBMOBIL domain. However, w.r.t. its conceptional foundation, it is designed to be used for the solution of a wide range of transfer ambiguities.

4.3 The System of Transfer Correspondences

In this section we will introduce a fine-grained, hierarchically structured system of transfer correspondence rules that directly reflects different translation problems and supports their resolution. The interaction between this rule system and a variety of translation phenomena is illustrated in section 5.

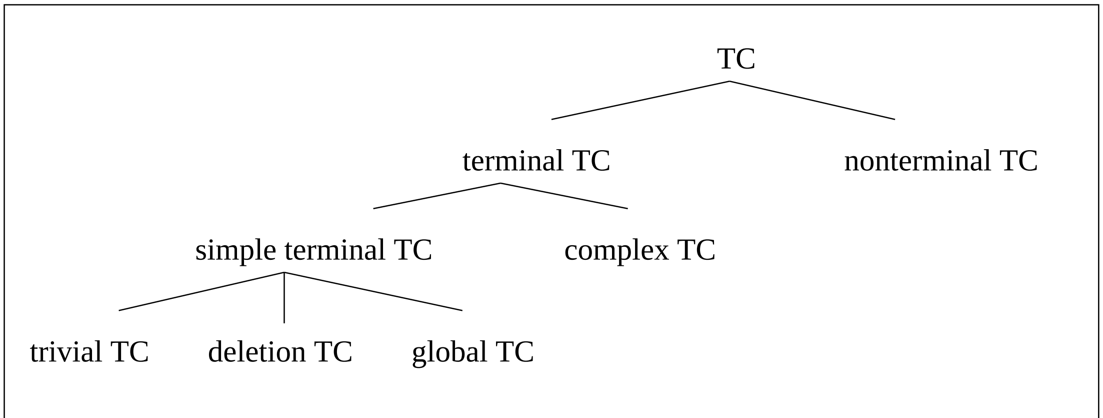

Figure 2: The MinT rule system

Let us first introduce the various kinds of *transfer correspondences* (TCs) which form the main knowledge base of MinT. Figure 2 gives an overview over the system of TCs. In general, a TC establishes an equivalence relation between (possibly empty) sets of relations, cf. (15).[16]

(15) $\langle \textit{set-of-relations} \rangle \leftrightarrow \langle \textit{set-of-relations} \rangle$

We distinguish two kinds of TCs, *terminal TCs* and *nonterminal TCs*, which model *bilingual equivalences* and *monolingual equivalences*, respectively.
Bilingual equivalences subsume all kinds of bidirectional mappings of SL semantic segments onto TL semantic segments. In the MRS-based transfer outlined here,

[16][Copestake et al., 1995] also describe transfer as relation between sets of source relations to sets of target relations. *Lexical equivalences* are specified as one-to-one mappings, and *phrasal equivalences* as one-to-many or many-to-many mappings.

bidirectional mappings are implemented by so-called *terminal transfer correspondences* (represented by "$\Leftrightarrow$").[17] Terminal TCs relate sets of source relations to sets of target relations (cf. (16)). A terminal TC always terminates the local translation goal.

(16) $\left\langle \textit{set-of-SL-relations} \right\rangle \Leftrightarrow \left\langle \textit{set-of-TL-relations} \right\rangle$

Monolingual equivalences subsume any kind of mappings from a semantic segment to another semantic segment *within* the same language. In the following, we will focus only on monolingual mappings in German, since we regard only the transfer direction German-English here. We use so-called *nonterminal transfer correspondences* (described by "$\Rightarrow$") that reorganize a set of source relations to a logically equivalent set of source relations, cf. (17). Nonterminal TCs model composition processes motivated by the contrastive data of a language pair. Nonterminal TCs do not terminate the local translation goal but serve to bridge the cleft between languages by providing more adequate semantic segments for the transfer process. Note that the output of a nonterminal TC has to be processed as long as it can be traced back to terminal TCs.

(17) $\left\langle \textit{set-of-SL-relations} \right\rangle \Rightarrow \left\langle \textit{set-of-SL-relations} \right\rangle$

4.3.1 Bilingual Transfer Correspondences

Under terminal TCs, we distinguish *simple TCs* (18) - (20) and *complex TCs* (21). Simple TCs are further subdivided into *trivial TCs* (18), *global TCs* (19) and *deletion TCs* (20).

(18) $\left\langle \textit{SL-relation} \right\rangle \Leftrightarrow \left\langle \textit{TL-relation} \right\rangle$

(19) $\left\langle \boxed{1} \left[\textit{SL-relation} \right] \right\rangle \Leftrightarrow \left\langle \boxed{1} \right\rangle$

(20) $\left\langle \textit{SL-relation} \right\rangle \Leftrightarrow \left\langle \right\rangle$

(21) $\left\langle \textit{SL-relation-1, SL-relation-2, } \ldots \right\rangle \Leftrightarrow \left\langle \textit{TL-relation-1, TL-relation-2, } \ldots \right\rangle$

[17] The notion of bilingual equivalence cannot be regarded as an equivalence in the strong logical sense. It is a well-known fact that translation is better viewed as a process of approximation, the degree of approximation depending on the domain-specific focus of the system (cf. [Kameyama et al., 1993]).

Trivial TCs represent the simplest form a transfer can take, e.g. the mapping of a feature structure of the type *telefon_rel* onto its English counterpart *telephone_rel* (cf. (22)).

(22)
$$\left\langle \begin{bmatrix} \textit{telefon\_rel} & \\ \text{HANDEL} & \boxed{1}\ \text{h-const} \\ \text{INST} & \boxed{2} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{telephone\_rel} & \\ \text{HANDEL} & \boxed{1} \\ \text{INST} & \boxed{2} \end{bmatrix} \right\rangle$$

With global TCs cross-linguistically invariant semantic categories, e.g. negation, referential information, or the various mood types, are directly handed over to the generation component.[18] Deletion TCs eliminate information that does not need to be transferred, e.g. certain discourse particles like *mal, so* or *da*. This, of course, presupposes that semantic analysis can identify the discourse reading of the particle. Complex TCs (21) establish a mechanism for treating phrasal expressions that cannot be treated compositionally as well as cases of generalization and specialization gaps.

4.3.2 Monolingual Transfer Correspondences

Nonterminal TCs establish a declarative mechanism for resolving translation divergences *within* the SL. By the application of a nonterminal TC, transfer initiates the decomposition or recomposition of semantic predicates to terminte a terminal TC, perhaps in several steps. (23) shows the general schema of this correspondence type.

(23)
$$\left\langle \textit{SL-relation-1, SL-relation-2, } \ldots, \textit{ SL-relation-m} \right\rangle \Rightarrow$$
$$\left\langle \textit{SL-relation-m+1, SL-relation-m+2, } \ldots, \textit{ SL-relation-n} \right\rangle$$

In section 5.3, we will exemplify how we utilize monolingual TCs to treat several types of translation divergences in MinT.

4.3.3 Bilinks

As [Sanfilippo and Copestake, 1993] have shown with their *tlink* concept, a lot of information that has to be transferred can be generalized in order to avoid errors and to specify transfer rules economically. We use a less powerful but more efficient variant for expressing bilingual generalizations, called *bilinks*. Bilinks form a monotonic knowledge base of their own and serve to instantiate the TC knowledge base in a precompilation step. From a logical point of view, bilinks can

[18] Global rules correspond exactly to the interlingual rules of [Copestake et al., 1995].

be compared with HPSG principles (cf. [Pollard and Sag, 1987]), i.e. as implications which model the principles of the contrastive grammar. For every input relation in the TC knowledge base, if subsumed by the input relation type of a bilink, the output relation of the TC is unified with the output relation of the bilink. In contrast to tlinks, bilinks are explicitly separated from the rule system and not ordered in a default-inheritance network.

To give a short example, the INDEX value of a nominal relation in a trivial TC is transferred by using the bilink in (24). The index-bilink captures the bilingual generalization that the number value but not the gender value of a nominal relation is preserved during translation from German to English.

(24)
$$\left\langle\begin{bmatrix} \textit{nom\_rel} \\ \text{INDEX} \mid \text{NUMBER} \;\; \boxed{1} \end{bmatrix}\right\rangle \underset{\text{inkdex-bi}}{\longleftrightarrow} \left\langle\begin{bmatrix} \textit{nom\_rel} \\ \text{INDEX} \mid \text{NUMBER} \;\; \boxed{1} \end{bmatrix}\right\rangle$$

4.3.4 Some Procedural Aspects of MinT

In this section we want to focus on some implementational issues.
The transfer operates on a list of feature structures whose elements are of the type relation. The knowledge base of the transfer module consists of a set of TCs which recur to the type hierarchies of semantic sorts and relations. Bilinks serve to simplify the writing of TCs in a precompiling step. For the sake of simplicity, we will ignore them here.
The transfer process proceeds as follows: The semantic analysis provides the transfer component with an input list which is processed relation by relation.[19] The presently salient relation is mapped onto the SL side of a TC. In our specific translation environment, this means mapping the German LHS onto the English RHS.
There are three possible ways of mappings. In the simplest case, a simple TC is applied. Then, the RHS of a TC is inserted into the TL list provided to the generator. In more complex cases, however, more than one relation is required to license the transfer rule. This is the case for complex and nonterminal TCs. If these rule types are triggered, a search of the input list is initiated to find the required SL relations. In the case of complex rules, the set of SL relations is then simply mapped onto a set of TL relations. But in the case of nonterminal rules, the input relations that had triggered the nonterminal TC are substituted

[19] In a non-incremental system, it makes sense to rearrange the input list w.r.t. to criteria of efficiency. The discovering of these citeria is one of the current topics of investigation at the IMS in Stuttgart. In the following, we simply assume an arbitrary ordering on the list.

by the RHS's relations, which are again SL relations. Transfer is continued with the transformed list.
We do not want say much about control here. But let us note that the transfer processor's selection strategy of competing TCs is guided by at least two heuristics: Nonterminal TCs are preferred to terminal TCs and complex terminal TCs take precedence over simple terminal TCs. Consequently, the processor always tries to find a complex mapping rule before a simple one. To make the transfer efficient, it is desirable to keep the number of complex rules as small as possible. These considerations show that it is necessary to separate the processing of idioms from the main transfer process.[20]

Transfer correspondences as well as bilinks can be processed bidirectionally just by changing the viewpoint of the transfer processor: If the translation direction is German to English (G-E) the German input relations are mapped onto the LHS of a TC and the RHS is either processed further in the case of nonterminal TCs or directed to generation in the case of terminal TCs. In the reverse case (E-G), the English input is mapped onto the RHS of a TC yielding the LHS as intermediate or final output.

In principle, incremental processing is supported by an MRS-based transfer system. Every subset of the input list could be used as incremental unit in a processing step. It would make sense to start incremental transfer by regarding all relations belonging to a referential object. Anyhow, we do not deal with incremental processing within Verbmobil.

5 Transfer Problems and their Treatment in MinT

In this section, we exemplify the treatment of translational phenomena which are known to pose problems to unification-based MT systems. We propose a categorization of transfer phenomena, which takes its origin in the classification of structural-semantic divergences outlined in [Dorr, 1993], the notions of generalization and specialization, cf. [Kameyama et al., 1991] and [Barnett et al., 1991], as well as the differentiations of translation phenomena in the lexical domain, suggested in [Kay et al., 1991] and [Buschbeck-Wolf, 1994].
W.r.t. the level of their appearance we distinguish among:

[20]Idioms are treated in a preprocessing step that operates on keywords. By the help of these keywords the idiom parser extracts all relations connected with an idiomatic phrase and substitute these by (a set of) content-bearing relations, labelled as being the source of an idiom.

1. translation phenomena at the lexical level
2. translation phenomena at the phrasal level
3. translation phenomena at the structural-semantic level

In the following, we will make explicit how the particular types of TCs introduced in the previous section are applied to the different kinds of translational phenomena. This is sketched in Figure 3.

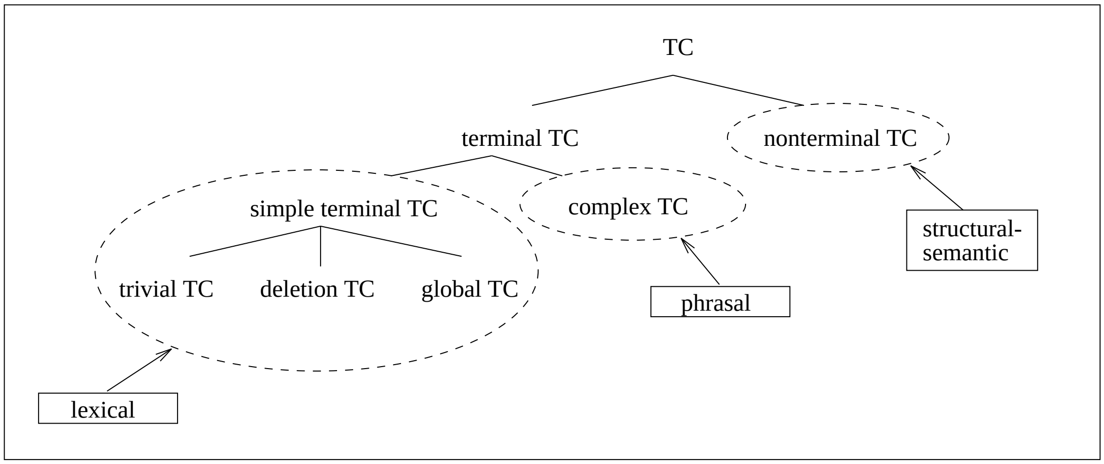

Figure 3: Correlations between different kinds of translation problems and TC to be applied

First of all, simple terminal TCs are applied to translational phenomena in the lexical domain. Complex terminal TCs capture phrasal ones, and nonterminal TCs cope with structural-semantic phenomena.
For the most part, we take examples from the VERBMOBIL domain, others recur to general problems which are well-known to pose problems to semantic-oriented MT and call for resolution.

5.1 Applications of Simple Terminal Transfer Correspondences

Simple terminal TCs establish bilingual correspondences between one SL-relation and one or no TL-relation. The following subsections show examples for the subtypes of simple TC, that are trivial TCs (18), global TCs (19) and deletion TCs (20).

5.1.1 Trivial TCs

A large amount of lemmata map to only one TL correspondence. In these cases, the mapping is trivial since no restrictions have to be fulfilled. In the first subsection, we exemplify the application of trivial TCs that illustrate the use of underspecified sorts and relations. In the following subsections, we take a closer look at the transfer of ambiguous verbs, nouns, prepositions, and adjectives.

5.1.1.1 The Use of Underspecification in Trivial TCs

In the simplest case of trivial TCs, the semantic relations are unambigous in the source and the target language, cf. (25).

(25) $$\left\langle \begin{bmatrix} \textit{stunde\_rel} & \\ \text{INST} & \boxed{1}\ \textit{temp\_period\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{hour\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle$$

There is another class of semantic relations that regularly displays the same range of ambiguities across languages. This phenomenon, which often shows up in the domain of nomimal predicates, is called systematic polysemy, cf. [Bierwisch, 1983], [Nunberg, 1979].

For example, the occurrences of *Universität* and *university* in the following expressions show that these lexical items are ambiguous in a parallel fashion. They may denote an institution (26a), a location housing the institution (26b), or a group of people associated with it (26c).

(26a) an der *Universität* arbeiten ↔ work at the *university*
(26b) die Haltestelle bei der *Universität* ↔ the stop next to the *university*
(26c) die *Universität* streikt ↔ the *university* is on strike

In order to preserve ambiguities that hold across languages, we make use of underspecified sortal specifications on the relation's instances.[21] This is shown by the TC in (28), which maps *universität_rel* with the disjunctively defined sort *inst_loc_coll_s* (cf. 27) to *university_rel*. In order to express the sortal ambiguity of systematically polysemous nouns, we declare disjunctive sortal types. The transfer leaves the specification of its institutional, spatial or staff reading underspecified.

[21]The sortal ambiguity of systematically polysemous nouns is expressed by disjunctive sortal types that are declared in the sort hierarchy. Disjunctive specifications in the transfer rules can thus be avoided.

(27) inst_loc_coll_s = institution_s;building_s;collective_s.

(28)
$$\left\langle \begin{bmatrix} \textit{universität\_rel} & & \\ \text{INST} & \boxed{1} & \textit{inst\_loc\_coll\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{university\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle$$

Other trivial TCs operate on underspecified semantic relations. Besides the various advantages mentioned in 4.1, the mapping of underspecified relations accounts for the fact that a SL expression can often be translated in different ways.
As outlined in 4.1.2, the underspecified relation *vorschlagen_rel* captures the verbal expression *vorschlagen*, its nominalization *Vorschlag* as well as the light verb construction *einen Vorschlag machen*. The TL correspondences *suggest*, *suggestion* and *make a suggestion* can be combined to a similar abstract semantic relation. Thus, a transfer mapping which abstracts over the various possible realizations, as presented in (29), is feasible.

(29)
$$\left\langle \begin{bmatrix} \textit{vorschlagen\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{suggest\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

The transfer output is then a semantic relation that leaves the syntactic realizations open to the generation component.

(30) Machen Sie bitte einen Vorschlag.
(30a) Make a suggestion, please.
(30b) Suggest something, please.
(30c) Suggest a date, please.
(30d) Your suggestion, please.

(30) shows a support verb construction, in which the addressee is realized as the unique overt argument of *vorschlagen_rel*. The most natural way to translate this is to select the corresponding English construction in (30a).[22] However, the generation component also has the option to use the main verb (30b). But then, in order to produce a grammatical sentence, the generator has to insert a dummy relation for the required theme argument, e.g. *something* in (30b), or a

[22]Note that the selection of the specific support verb is also not stipulated by the transfer module.

specific lexicalization if inferable from the context (30c). Although the use of a pure nominalization is often blocked, it is possible in imperative sentences (30d). Here, the suggesting person functions as the first argument of the nominalization. Note that here it is justifiable that the tense information gets lost during translation.

On the other hand, there are lots of translational ambiguities, which arise when the different meanings of a SL lexical item have to be mapped onto different TL words. These problems are often caused by homonymy or polysemy. Although it can be observed that homonyms have almost always different translation correspondences, and polysemes might have the same translation, cf. (26), from a practical point of view it makes little sense to differentiate between translational ambiguities w.r.t. the closeness of the particular meanings a lexical item provides (cf. [Kay et al., 1991]). Therefore, we expect the transfer component to operate on relation names neutral w.r.t. ambiguities.[23]

5.1.1.2 Transfer of Verbal Predicates with Trivial TCs

The translation of *verlegen* differs w.r.t. its different readings in (31) - (35).
(31) einen Termin *verlegen* ⇔ *postpone* an appointment
(32) ein Buch *verlegen* ⇔ to *publish* book
(33) eine Firma *verlegen* ⇔ to *transfer* a company
(34) ein Kabel *verlegen* ⇔ to *lay* a wire
(35) einen Notizzettel *verlegen* ⇔ to *misplace* a note

The different readings can be captured by sortal restrictions on the lower argument. The corresponding TCs are shown in (36) - (39).[24]

(36)
$$\left\langle \begin{bmatrix} \textit{verlegen\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \\ \text{ARG3} & \boxed{3} & \textit{info\_medium\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{publish\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

[23]In some cases, ambiguities have to be resolved already in syntactic or semantic analysis, since they may cause a distinct syntactic or semantic behavior, such as the different categories two homonyms may belong to.

[24]The *postpone*-reading of *verlegen*, identified by an ARG3 of the sort *event_s*, is captured by the TC represented in (88), in 5.2. This TC maps an underspecified relation that abstracts over the various ways to express appointment rescheduling situations.

(37)
$$\left\langle \begin{bmatrix} \textit{verlegen\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \\ \text{ARG3} & \boxed{3} & \textit{institution\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{transfer\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

(38)
$$\left\langle \begin{bmatrix} \textit{verlegen\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \\ \text{ARG3} & \boxed{3} & \textit{carpet\_s;cable\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{lay\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

(39)
$$\left\langle \begin{bmatrix} \textit{verlegen\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \\ \text{ARG3} & \boxed{3} & \textit{artefact\_s \& moveable\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{misplace\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

As this example shows, it may happen that more than one rule fires although the relation's lower argument is sorted in a fine-grained way. For instance, the sortal specifications of the *misplace*-rule subsume the more specific ones in the *lay*-rule and in the *publish*-rule. An information medium as well as a carpet or a cable[25] satisfy the sortal restriction of the *misplace*-reading because they are also moveable artefacts. The difference between them cannot be fixed by sortal restrictions alone. Here, a broader context, which is provided by the semantic evaluation component, is needed in order to make a decision.

5.1.1.3 Transfer of Nominal Predicates with Trivial TC

The transfer of ambiguous nouns poses difficulties to every MT system since the verification of sortal restrictions turns out to be extremely complicated. One of these examples is the translation of *Termin*. As shown in (40)-(42), the choice of the TL correspondence depends on whether it refers to a kind of event, a date, or a time slot.

[25]It is important to keep the number of disjunctions in sortal restrictions as small as possible by trying to define more general sorts.

(40) den *Termin* verlegen/verschieben $\Leftrightarrow$ reschedule the *appointment*
(41) der *Termin* passt mir nicht $\Leftrightarrow$ this *date* does'nt suit me
(42) einen *Termin* frei haben $\Leftrightarrow$ have an *appointment slot* free

The TCs in (43) - (45) show how *termin_rel* is mapped onto its TL correspondences, thereby respecting the sort of the relation's instance. In some cases, the selectional restrictions of other relations in the context of *termin_rel* may force a particular reading, such that only one rule is applicable. However, constraints that other relations call for are often not restrictive enough.

(43) $$\left\langle \begin{bmatrix} \textit{termin\_rel} & \\ \text{INST} & \boxed{1}\ \textit{event\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{appointment\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle$$

(44) $$\left\langle \begin{bmatrix} \textit{termin\_rel} & \\ \text{INST} & \boxed{1}\ \textit{day\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{date\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle$$

(45) $$\left\langle \begin{bmatrix} \textit{termin\_rel} & \\ \text{INST} & \boxed{1}\ \textit{temp\_period\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{appointment\_slot\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle$$

If the instance's sorts of the incoming relation is not as specific as one of the TCs in (43) - (45) requires, more than one rule fires. In this case, a request for further resolution is sent to the semantic evaluation component. This module has to determine which of the two or more sorts is adequate in the given context. If this cannot be figured out a default-based solution has to be provided.

As a further example, we consider greeting and farewell formulas. Such formulas can be transferred on an abstract level that leaves the actually used expression underspecified. On the one side, these are single words, such as *hallo*, *ade* or *tschüss*, and on the other, these are multi-word expressions that cannot be translated compositionally, as e.g. *guten Morgen*, *grüss Gott* or *auf Wiedersehen*. For the latter cases, we assume that the semantic analysis provides us with a relation complex that is preprocessed in the semantic evaluation component. If a relation complex is identified as a salutation formula it is mapped onto a more abstract relation that covers the intended meaning and holds across the languages involved.[26]

Figure 4 represents the relevant parts of the SL and TL hierarchies for salutation relations.

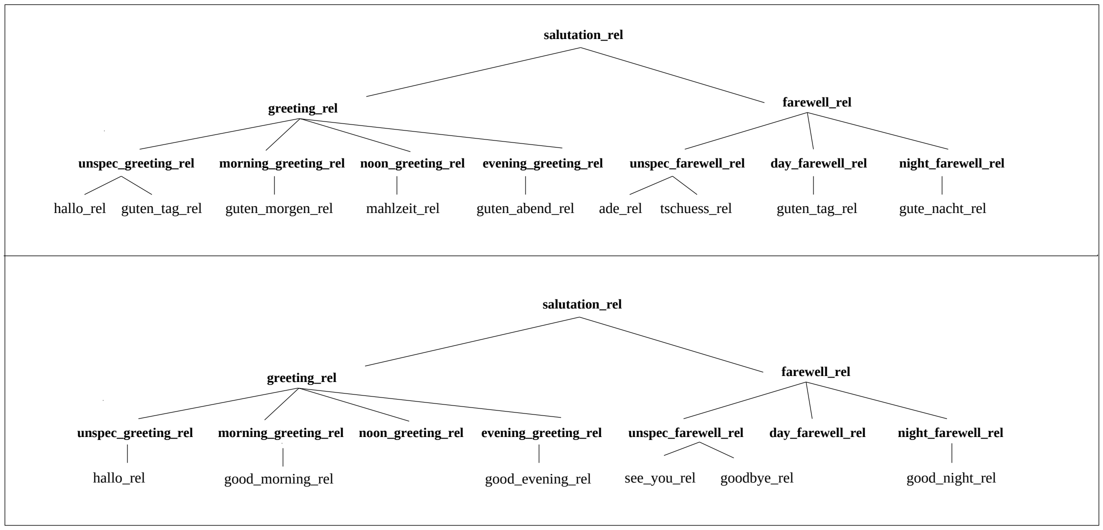

Figure 4: Hierarchical relations in the domain of salutation formulas

Applying trivial TCs, as shown in (46) - (48), the contextually relevant salutation relation is passed to the generator that is given the option to lexicalize them according to the corresponding subtypes specified in the TL relation hierarchy.

(46) $$\left\langle\begin{bmatrix} \textit{unspec\_greeting\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{unspec\_greeting\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle$$

(47) $$\left\langle\begin{bmatrix} \textit{unspec\_farewell\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{unspec\_farewell\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle$$

(48) $$\left\langle\begin{bmatrix} \textit{unspec\_morning\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{unspec\_morning\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle$$

[26] In some cases greeting formulas are also used to say goodbye, such as *guten Tag* or *Mahlzeit*. In order to assign the appropriate relation, the semantic evaluation component has to consult the dialogue history that provides information about the dialogue stage.

5.1.1.4 Transfer of Prepositional Predicates with Trivial TCs

Another example for the application of trivial TCs is the transfer of ambiguous prepositions. Adverbial as well as predicative PPs are semantically analyzed as modifiers. The general strategy will be to translate prepositions on a rather abstract level. Using trivial TCs, the SL preposition is assigned an abstract relation that captures the contextually relevant meaning. For the identification of these relations, the TCs make extensive use of sortal specifications on the arguments of the preposition. The identified abstract relation together with the sortal constraints on the arguments function as the input to the generator. Thus, the generator has all information necessary to derive the appropiate TL preposition. Prepositions are cross-classified w.r.t. three dimensions:

1. directional vs. static use
2. level of semantic abstraction
3. level of conceptual interpretation

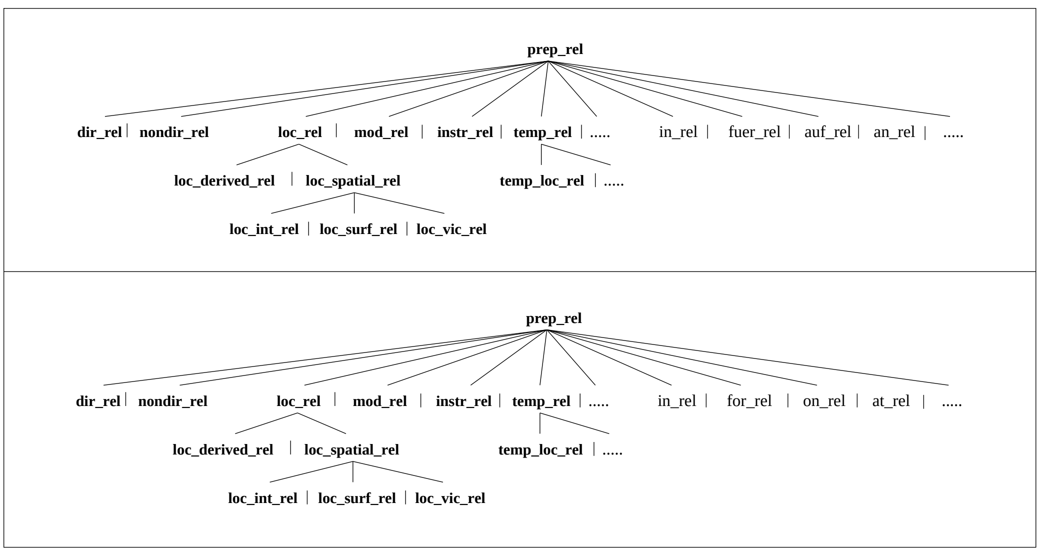

Figure 5: Cross-classification of prepositional relations in the relation hierarchy

Figure 5 shows how this information is organized in the SL and TL relation hierarchies.[27]

[27] The depth of the conceptual interpretation depends on the demands of the generator and the allocation of tasks between transfer and generation.

The semantic analysis component provides information about the directional or non-directional use of a preposition. Together with the preposition-specific relation this information forms the input to the transfer module. The range of a preposition's meaning is determined by the intersection of the introduced relations and the sortal specification of its arguments. In the following, we illustrate the transfer of the preposition *in*.

(49a) das Treffen *im* Januar ⇔ the meeting *in* January
(49b) die Vorlesung *in* dieser Woche ⇔ the lecture this week

(50a) die Eingangshalle *im* Hotel ⇔ the entrance hall *in* the hotel
(50b) das Büro *im* Erdgeschoss ⇔ the office *on* the ground floor

(51) das Treffen *in* der Universität ⇔ the meeting *at* the university

(52a) die Studenten *in* der Vorlesung ⇔ the students *at* the lecture
(52b) *im* Urlaub sein ⇔ to be *on* holidays

(53) etwas *in* Eile tun ⇔ to do sth. *in* a hurry

Examples (49) - (53) show some of the static interpretations of *in*. These are the temporal localization (49), the localization in the interior of a location or an object (50), the localization w.r.t. an institution (51), the temporal-spatial localization (52) and the modal interpretation (53). The TCs in (54) - (58) illustrate how these particular meanings can be identified by imposing sortal constraints on the internal argument.

(54)
$$\left\langle \begin{bmatrix} \textit{in\_rel \& nondir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{temp\_obj\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{temp\_loc\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix} \right\rangle$$

(55)
$$\left\langle \begin{bmatrix} \textit{in\_rel \& nondir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{three\_dim\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{loc\_int\_rel \& nondir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix} \right\rangle$$

(56)
$$\left\langle \begin{bmatrix} \textit{in\_rel \& nondir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{event\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{loc\_derived\_rel \& nondir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix} \right\rangle$$

(57)
$$\left\langle \begin{bmatrix} \textit{in\_rel \& nondir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{institute\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{loc\_derived\_rel \& nondir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix} \right\rangle$$

(58)
$$\left\langle \begin{bmatrix} \textit{in\_rel \& nondir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{property\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{mod\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix} \right\rangle$$

Instead of directly mapping the SL preposition's relation onto an appropriate TL preposition, the SL preposition is assigned a conceptual interpretation that leaves alternative lexicalizations up to the generator. For example, the temporal localization *temp_loc_rel* can either be lexicalized with English *in* (49a) or is omitted if the temporal expression is deictically referred to (49b). The localization in an object's interior (55) can be expressed by *in*, if the internal argument is viewed three-dimensionally (50a), or by *on* if it is conceptualized two-dimensionally (50b). The derived temporal-spatial localization that is recognized by an internal argument of the sort *event_s* (57) is verbalized with *on* if the lemma *holiday* occurs as its internal argument (52b) and otherwise with *at* (52a). For the interpretations in (56) and (58) only one lexicalization is feasible. It is determined by the relation and the sortal specification.
In this example, directional interpretations systematically correspond to static relations. They often can be analyzed using the same sortal restrictions as the latter. The following examples illustrate the directional interpretations that correspond to the static ones in (55), (56) and (57).[28]

(59a) *in* das Büro gehen ⇔ go *to/into* the office
(59b) *in* die zweite Etage kommen ⇔ come *to* the second floor
(59c) die Fahrt *in* die Schweiz ⇔ the trip *to* Switzerland

(60) *in* die Schule gehen ⇔ go *to* school

[28] For the transfer of temporal directionals that cannot be handled by trivial TCs, see 5.2.

(61a) *in* die Vorlesung gehen $\Leftrightarrow$ go *to* the lecture
(61b) *in* den Urlaub fahren $\Leftrightarrow$ go *on* holidays

These interpretations can be captured by the following TCs:

(62)
$$\left\langle\begin{bmatrix} \textit{in\_rel \& dir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{three\_dim\_s} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{loc\_int\_rel \& dir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix}\right\rangle$$

(63)
$$\left\langle\begin{bmatrix} \textit{in\_rel \& dir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{event\_s} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{loc\_derived\_rel \& dir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix}\right\rangle$$

(64)
$$\left\langle\begin{bmatrix} \textit{in\_rel \& dir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{2} & \textit{institute\_s} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{loc\_derived\_rel \& dir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix}\right\rangle$$

Concerning the derivation of the appropriate TL preposition, only the TL relation in (62) poses difficulties. In the case of geographical objects, *to* has to be selected. For buildings and rooms, except for floors, which are viewed as two-dimensional entities in English, the lexicalization with *to* as well as with *into* is possible, cf. (59a). The choice of the appropriate TL preposition depends on the perspective on the situation: *go to the university* means to go in its direction, *go into the university* means to enter it. The resolution of this problem needs further evaluation. In the VERBMOBIL domain, spatial goals mostly occur in descriptions of directions where the speaker usually has a distant perspective. Thus, *from* seems to be the preferred translation. If a temporal-spatial localization is the goal of a movement (63) English *to*, or *on* in the holiday case, has to be generated. *To* is also appropriate if an institution turns out to be the goal of a movement (60).
For unambiguous prepositions, the translation mapping is straightforward. Here, the transfer module provides the TL preposition along with its conceptual interpretation, cf. (65):

(65)
$$\left\langle\begin{bmatrix} \textit{während\_rel \& temp\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{during\_rel \& temp\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{2} \end{bmatrix}\right\rangle$$

In the VERBMOBIL demonstrator, [Buschbeck-Wolf and Nübel, 1995] proposed a pure interlingual approach for the translation of prepositions. An underspecified prepositional meaning had been refined to a very specific contextually relevant one. In the model proposed here, just the information necessary for a preposition's translation is passed to the generator. Thus, redundancy problems can be avoided.

Next we will show how to deal with idiosyncratic prepositions that show up in the context of verbs, nouns or adjectives. (66) shows an example:

(66) Er denkt *ans* Heiraten.
He thinks *of* marrying.

This case is problematic because one participant of the situation is provided by the complement of the preposition, which is idiosyncratically selected by *denken*. In (66) *marrying* is the theme of the thinking situation.
From the cross-linguistic perspective, it is hard to find systematic correspondences between prepositions that are selected by verbs. Taking into account that the preposition's own meaning is very marginal, these prepositions are best analyzed as being melted with their verbal predicate, thus yielding a complex predicate. In the given example, the complex SL predicate can be related directly to that of the TL by the trivial TC in (67).

(67)
$$\left\langle \begin{bmatrix} \textit{denken\_an\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \textit{abstract\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{think\_of\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

Interesting enough, a variant is possible where the theme of the situation is accessed directly and not via the preposition, cf. (68):

(68) Er denkt Blödsinn.
He is thinking nonsense.

But this case does not pose problems to the analysis suggested here, because we can differentiate between the simple and the complex predicate. The corresponding TC is shown in (69).

(69)
$$\left\langle\begin{bmatrix} \textit{denken\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \textit{abstract\_s} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{think\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix}\right\rangle$$

5.1.1.5 Transfer of Adjectival Predicates with Trivial TCs

To conclude the discussion on trivial TCs, let us take a closer look at the translation of adjectives with collocative use. The following examples illustrate the difficulties in transferring adjectives that have a metaphorical meaning beside their literal one, cf. (70): these adjectives denote a high intensity w.r.t. to the modified situation, property or referent, cf. (71).

(70) ein *schwerer Koffer* ⇔ a *heavy* suitcase
ein *schwerer* Mann ⇔ a *heavy* man

(71) ein *schwerer* Unfall ⇔ a serious accident
ein *schwerer* Wein ⇔ a *heavy* wine
ein *schwerer* Schock ⇔ a *severe* shock
eine *schwere* Geburt ⇔ a *difficult* birth
ein *schwerer* Tag ⇔ a *hard* day

One might think of treating the translation correspondences between such adjectives very specifically by stating a trivial TC for every case, cf. (72) - (75).

(72)
$$\left\langle\begin{bmatrix} \textit{schwer\_rel} & & \\ \text{INST} & \boxed{1} & \textit{accident\_s;disease\_s; \ldots} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{serious\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix}\right\rangle$$

(73)
$$\left\langle\begin{bmatrix} \textit{schwer\_rel} & & \\ \text{INST} & \boxed{1} & \textit{shock\_s;suffering\_s;\ldots} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{severe\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix}\right\rangle$$

(74)
$$\left\langle\begin{bmatrix} \textit{schwer\_rel} & & \\ \text{INST} & \boxed{1} & \textit{task\_s;birth\_s} \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} \textit{difficult\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix}\right\rangle$$

(75) $\left\langle\begin{bmatrix} schwer\_rel \\ \text{INST} \quad \boxed{1} \quad concrete\_s \end{bmatrix}\right\rangle \Leftrightarrow \left\langle\begin{bmatrix} heavy\_rel \\ \text{INST} \quad \boxed{1} \end{bmatrix}\right\rangle$

The TCs in (72) - (75) show how the TL counterpart of *schwer* can be identified by the use of sortal constraints on the modificandum. While the metaphorical translation is determined by very specific sortal contraints, the literal translation is assigned if the modificandum is a concrete thing that intrinsically has a weight. However, this approach would multiply the number of TCs that also turn out to be very specific. The translation depends on particular nouns that cannot be grouped together by means of an upper-level sort in the sort hierarchy. In addition, the application of TCs such as in (72) - (75) has some further drawbacks. Take a look at Table 1.

schwer	stark	hart
ein schwerer Unfall	*ein starker Unfall	*ein harter Unfall
ein schwerer Wein	ein starker Wein	*ein harter Wein
ein schwerer Schock	ein starker Schock	*ein harter Schock
eine schwere Geburt	*eine starke Geburt	?eine harte Geburt
ein schwerer Tag	*ein starker Tag	ein harter Tag

Table 1: Examples for possible and impossible collocations with *schwer*, *stark* and *hart*

There is a large amount of adjectives that express the meaning of intensity in the given context. It is hard to predict which of them can be used with a particular noun and which cannot. Furthermore, the complexity of transfer relations still increases since the English language provides a similar but not identical idiosyncratic behavior of adjectives.
If we directly establish all possible correspondences between German and English intensity expressing adjectives depending on the particular nouns they occur with, their number would increase significantly. Moreover, this straightforward analysis does not seem to be conceptually adequate. It does not account for the meaning components they have in common.
For these reasons, we propose to treat adjectives in collocative use by tracing back parts of the expressions to more abstract semantic relations that are regarded to be bilingual. Similar to [Melchuk et al., 1984], who analyzed those expressions by means of a *lexical function* called **Magn**[29], we analyze adjectives, such as

[29]For example, **Magn**(Raucher) = stark and **Magn**(smoker) = heavy

schwer, as having either a literal reading, or specifying a positive intensity of the modified individual.

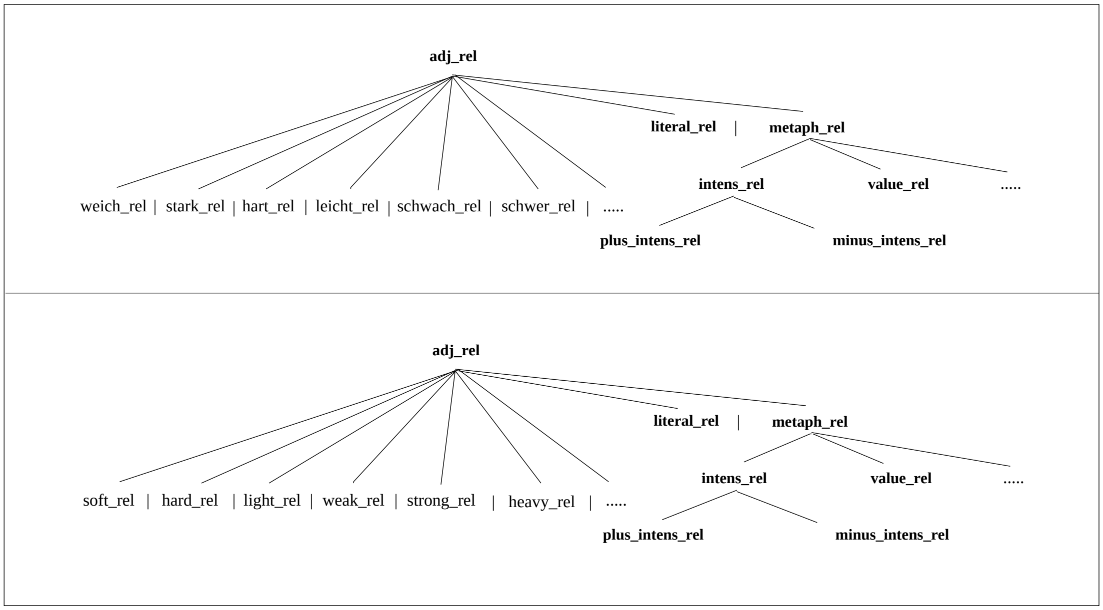

Figure 6: Part of the hierarchy of adjective relations

The distinction between the literal and the metaphorical interpretation is anchored in the relation hierarchy, where metaphorical relations are described w.r.t. the meaning they cover, cf. Figure 6.
By verifying selectional restrictions, the semantic analysis provides the transfer module with the contextually relevant relation, such that the TC become very simple. In case the literal interpretation has been determined, a trivial TC provides the concrete TL correspondence, cf. (76).

(76) $$\left\langle \begin{bmatrix} \textit{schwer\_rel \& literal\_rel} \\ \text{INST} \quad \boxed{1} \quad \textit{concrete\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{heavy\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix} \right\rangle$$

If *schwer* was assigned the metaphorical interpretation the mapping is carried out on an abstract level, without transmitting the language-specific subtypes, cf. (77).

(77) $$\left\langle \begin{bmatrix} \textit{plus\_intensive\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{plus\_intensive\_rel} \\ \text{INST} \quad \boxed{1} \end{bmatrix} \right\rangle$$

5.1.2 Deletion TCs

Deletion TCs eliminate information which does not have to be transferred, as e.g. particular kinds of discourse particles. We are aware that the elimination of linguistic elements during transfer is a delicate matter. The dropping of a discourse particle in German may change the overall information structure which must be reflected in the TL. Nonetheless, weighing these minimal effects to the cost of analysis, we think that the use of deletion rules is justifiable in VERBMOBIL. Compared with German, English has an impoverished use of particles and filler words. Consequently, particles can often be dropped in the English translation. In order to eliminate a semantic relation introduced by a particle, its meaning has to be identified. To give an example, depending on whether the particle *noch* occurs as focus-sensitive particle or as discourse-functional filler, it is either translated or eliminated during transfer.
In case *noch* has to be translated, it corresponds to different English particles depending on its scope. If *noch* has scope over an individual that shows up with a cardinal number, *another* is its appropriate translation. Having scope over an event *noch* is translated either into *still* or into *yet*, depending on the polarity.

A further case where deletion TCs are applied is the use of the adverbial *da*. [30]. On the one hand, *da* can be used anaphorically, referring to a time or location anchored in the previous context, cf. (78) - (79)[31]

(78) Wie wär's mit Montag? - *Da* hab' ich schon einen Termin. ⇔
How about Monday? - I already have an appointment, *then*.

(79) Ich war in Mallorca. - *Da* bin ich auch schon gewesen. ⇔
I have been to Mallorca. - I already have been *there*, too.

On the other hand, the reference of *da* can be rather vague, involving the whole communication situation without any correspondence to an explicit antecedent. In (80), *da* seems to function as a discource filler used to keep the dialogue going or to make it coherent in some sense.

(80) *Da* könnte ich Ihnen den Montag anbieten. ⇔
I could suggest Monday to you.

If this reading of *da* is analyzed, the deletion rule in (81) can be applied.

[30] For an investigation on the use of *da*, see [Hamp, 1995]

[31] For the sake of simplicity, we do not consider the deictic use of *da*.

(81) $$\left\langle \begin{bmatrix} \textit{da\_disc\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \right\rangle$$

5.1.3 Global TCs

Cross-linguistically invariant semantic categories can be transferred by directly passing their information to the generator. For example, the mood information can be kept constant between German and English.

(82) $$\left\langle \boxed{1} \begin{bmatrix} \textit{prag\_mood\_rel} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \boxed{1} \right\rangle$$

(83) prag_mood_rel = decl_rel | interrog_rel | imperat_rel.
interrog_rel = polar_rel | wh_quest_rel.

In particular, the SL comes along with a specific subtype of *prag_mood_rel* (83) that instantiates a more general type given in the TC in (82).
In principle, all kinds of interlingual predicates that can be kept constant between two languages are transferred by global TCs. For the German-English language pair , these are, e.g., negation and particular tense and aspectual relations.

5.2 Applications of Complex Terminal TCs

Complex rules provide a mechanism to transfer bigger parts of the semantic representation as a whole. Complex TCs are applied to phrasal expressions that cannot be translated word by word since their meaning does not correspond to the meanings of their parts. Some of them are shown in (84).

(84) auf jeden Fall ⇔ in any case
auf einmal ⇔ at once
in Ordnung ⇔ okay

(85) shows the complex TC applied to transfer the expression *in Ordnung*.

(85) $$\left\langle \begin{bmatrix} \textit{in\_rel} & \\ \text{HANDEL} & \boxed{1} \\ \text{INST} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix}, \begin{bmatrix} \textit{ordnung\_rel} & \\ \text{HANDEL} & \boxed{4} \\ \text{INST} & \boxed{3} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{okay\_rel} & \\ \text{HANDEL} & \boxed{1} \\ \text{INST} & \boxed{2} \end{bmatrix} \right\rangle$$

As has been noted in section 4.3.4, idioms are treated in a preprocessing step that operates on keywords. By the help of these keywords the idiom parser extracts all relations connected with an idiomatic phrase. The relations corresponding to an idiomatic expression are substituted by (a set of) content-bearing relations. As far as this information might be useful for the generator, these relations are labelled as being the source of an idiom. For example the unanalyzed semantics of *in den sauren Apfel beissen* could be related to the descriptive content of "etwas akzeptieren müssen" which again could be translated either as *to have to accept sth.*, or as *to swallow the bitter pill.*
Furthermore, complex TCs are used to transfer temporal prepositions that show up in directional PPs. In contrast to spatial directional prepositions, their translation depend mostly on the translation of their head verb or noun, cf. (86), so that they cannot be processed compositionally by trivial TCs, see discussion in 5.1.1.

(86) den Termin *auf* Montag verlegen
(86a) *postpone* the appointment *until* Monday
(86b) *move* the appointment *to* Monday
(86c) *put off* the appointment *till* Monday
(86d) *reschedule* the appointment *for* Monday

Moreover, German displays alternative uses of temporal prepositions with verbs expressing rescheduling situations. Depending on the time expression, other prepositions than *auf* can be used, cf. (87).

(87a) den Termin *auf* Montag verlegen
(87b) den Termin *in* den Mai verlegen
(87c) den Termin *an* das Ende der Woche verlegen

The alternation of the German directional preposition does not effect the choice of the TL preposition. Regardless of the German preposition, *postpone until*, *move to*, *put off till*, and *reschedule for* are all appropriate translations for each of the examples in (87).

In order to account for the alternative use of SL prepositions and the various ways to express the rescheduling of an appointment, the use of an underspecified relation provides a solution. Similarily to (4) in 4.1.1, an abstract type, let us call it *abstr_resched_rel*, is introduced. It covers the concrete German and English expressions represented as its subtypes in Figure 7.

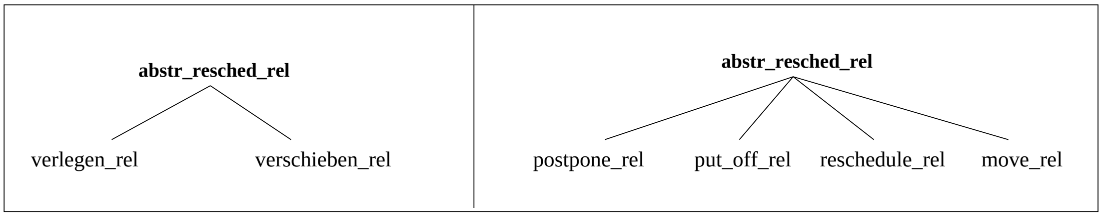

Figure 7: The abstract rescheduling relation and their language-specific relations

The introduced type allows the transfer of these verbs by the trivial TC in (88).

(88)
$$\left\langle \begin{bmatrix} \textit{abstr\_resched\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \textit{event\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{abstr\_resched\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

Now consider the complex TC in (89) that copes with these verbs when occurring with a directional PP:

(89)
$$\left\langle \begin{bmatrix} \textit{abstr\_resched\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \textit{event\_s} \end{bmatrix}, \begin{bmatrix} \textit{prep\_rel} \;\&\; \textit{dir\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG3} & \boxed{4} & \textit{temp\_obj\_s} \end{bmatrix} \right\rangle$$
$$\Leftrightarrow \left\langle \begin{bmatrix} \textit{abstr\_resched\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix}, \begin{bmatrix} \textit{prep\_rel} \;\&\; \textit{dir\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG3} & \boxed{4} \end{bmatrix} \right\rangle$$

The complex TC in (89) combines abstractions at different levels. While the relation *abstr_resched_rel* bundles the synonymous expressions for appointment rescheduling situations, we account for the variation of the German prepositions, cf. (87), by means of the underspecified relation *prep_rel*, the internal argument being restricted to time objects. Moreover, *prep_rel* allows the generator to select the appropriate TL preposition depending on the chosen verb.
This way, a large amount of rules, which capture the possible combinations of the synonymous verbs with their varying prepositions and the alternative translation

correspondences, can be compactly represented by a unique complex TC.

Complex TCs also serve to treat generalization and specialization gaps (cf. [Kameyama et al., 1991]. We are faced with the situation that one language does not provide a lexical item that covers the denotation of the corresponding expression in the other language. Depending on the direction of translation it designates either subsets or supersets of it. Examples are the German *Wand-Mauer* distinction of walls that is not made in English, or the English distinction between *watch* and *clock* that is not made in German. In the case of a specialization into the TL, we are forced to make a choice between two lexical items, which poses great difficulties. Since words like *Wand* and *Mauer* are close to each other in a taxonomical hierarchy, they occur in similar contexts. This makes it very complicated to formulate the contextual restrictions which force the use of either one or the other. Usually it is not necessary to choose between different lexical items in the case of a generalization into the TL, since we can use the more general TL expression. Anyhow, taking the more general predicate causes the loss of information. It has to be put in a context which accommodates the lost information.
A crucial case is the conjunction of the two specific SL expressions in (90):

(90) Wir haben dicke Mauern und Wände.
(90a) *We have thick walls and walls.
(90b) We have thick walls.

The translation in (90a) is simply bad. Here the lost information has either to be made explicit, or to avoid redundancy, the conjunction has to be combined, as shown in (90b).
Let us look at the translation of the German *stellen* or *legen* for which English provides no equivalent. The closest way to express their content is the use of *put* which leaves the final position of the moved object (which is vertical in the case of *stellen* and horizontal in the case of *legen*) unspecified. In order to establish an equivalence relation between *stellen_rel* or *legen_rel* and *put_rel* in (91) and (92), we make use of the additional relations *vert_pos_rel* and *hor_pos_rel* which accommodate the lost information about the object's position.

(91)
$$\left\langle \begin{bmatrix} \textit{stellen\_rel} & & \\ \text{INST} & \boxed{1} & \textit{move\_sit\_s} \\ \text{ARG1} & \boxed{2} & \textit{animate\_s} \\ \text{ARG3} & \boxed{3} & \textit{moveable\_s} \ \& \ \textit{axis\_obj\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{put\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix}, \begin{bmatrix} \textit{vert\_pos\_rel} & \\ \text{INST} & \boxed{3} \end{bmatrix} \right\rangle$$

(92)

$$\left\langle \begin{bmatrix} \textit{legen\_rel} & & \\ \text{INST} & \boxed{1} & \textit{move\_sit\_s} \\ \text{ARG1} & \boxed{2} & \textit{animate\_s} \\ \text{ARG3} & \boxed{3} & \textit{moveable\_s} \;\&\; \textit{axis\_obj\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{put\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix}, \begin{bmatrix} \textit{hor\_pos\_rel} & \\ \text{INST} & \boxed{3} \end{bmatrix} \right\rangle$$

In order to use the German motion verb *stellen* for putting an object on a surface, the object must be movable and must have distinguishable axis[32], while *legen* can potentially be used with every movable object. For objects with an intrinsic vertical axis (cf. [Lang, 1987]) such as bottles, glasses, or chairs, the use of *stellen* is preferred. For objects with an intrinsic horizontal axis, such as papers, knives, or pencils, and things that do not have an axis, *legen* is more appropriate. However, there are contexts in which objects with an intrinsic vertical axis are located by *legen* and things with an intrinsic horizontal or no axis are placed by *stellen*. This is the reason why the selectional restrictions fixed on the arguments have to be rather weak.

The information to be accommodated (in our case *vert_pos_rel* and *hor_pos_rel*) is marked as being of a special subtype *accomodation_rel* which leaves its lexicalization open to generation.[33] Consider the following expressions:

(93a) den Terminkalender auf den Tisch *legen*
(93b) den Terminkalender auf den Tisch *stellen*

(94a) to *put* the diary on the table
(94b) to *put* the diary *upright* on the table

For both patterns in (93), (94a) is a correct translation. Regarding (94a) as translation of (93a), the lost information on the diary's final position need not be accommodated because it has the position one usually expects. Here, the lost information is accommodated by commonsense knowledge on the typical object position. In (93b), however, we are faced with a rather unusual localization. If the lost information is not encoded elsewhere in the context, the generator has to make the position explicit by producing an output such as in (94b).[34]

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[32]With objects without axis, *stellen* cannot be used, cf. **den Lappen auf den Tisch stellen* (*put the cloth upright on the table).

[33]Technically speaking, a type *accomodation_rel* is introduced on the top level of the hierarchy that is non-disjunct with respect to other relations.

[34]Concerning the translation of *put* into German, the relation to be accommodated brings up information to select the appropriate German correspondence. To make the decision, the sortal restrictions are often too weak, such that further contextual knowledge is required.

This specific mapping operation, i.e. the mapping of an input relation onto a TC with the relation itself and an extra *accomodation_rel*, stands in significant contrast to other mappings and is used as the computational basis for discovering and perhaps evaluating such lexical gaps. Note that a mismatch of type generalization/specialization is recognized regardless of the transfer direction.

5.3 Applications of Nonterminal Transfer Correspondences

In this section, we give some examples for the application of nonterminal TCs that are used to map a SL semantic representation to a logically equivalent semantic representation within the SL. As outlined in section 4.3.2, nonterminal TCs are used to bridge divergences in the logical structure of two languages. Nonterminal TCs provide an alternative monolingual equivalent structuring to which terminal TCs can be applied.

It is well-known that incorporation of lexical material is a frequently occurring cross-linguistic phenomenon, cf. [Baker, 1988]. If not represented in the same way in SL and TL, incorporation may cause translation divergences, cf. [Dorr, 1993]. Some examples are shown in (95) - (98).

(95) sich verwählen $\Leftrightarrow$ to dial the wrong number
(96) eine Prüfung nicht bestehen $\Leftrightarrow$ to fail an exam
(97) jmd. ist etwas lieber $\Leftrightarrow$ sb. prefers sth.
(98) in einen Raum gehen $\Leftrightarrow$ to enter a room

(95) exemplifies a case of argument incorporation and (96) the incorporation of the negation operator. In (97), the predicate of the copula is included in the English verb, and in (98), the directional preposition is incorporated into the motion verb.

Let us consider the application of the nonterminal TC (99) for the case of argument incorporation in (95).[35] In nonterminal TCs, one must take care to establish the correct coindexing between the LHS and RHS handels, roles and instances.

[35] There exists a direct translation of *verwählen* with *misdial* but which is not in common use anymore.

(99)

$$\left\langle \begin{bmatrix} \textit{verwählen\_rel} & & \\ \text{HANDEL} & \boxed{4} & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \end{bmatrix} \right\rangle \Rightarrow \left\langle \begin{bmatrix} \textit{wählen\_rel} & \\ \text{HANDEL} & \boxed{4} \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix}, \begin{bmatrix} \textit{nummer\_rel} & \\ \text{HANDEL} & \boxed{5} \\ \text{INST} & \boxed{3} \end{bmatrix}, \begin{bmatrix} \textit{falsch\_rel} & \\ \text{HANDEL} & \boxed{5} \\ \text{INST} & \boxed{3} \end{bmatrix} \right\rangle$$

The *ver*-prefix is analyzed as an incorporated argument of a situation's relation. We assume that it binds the second argument position. The TC in (99) decomposes *verwählen_rel* into its morphological stem *wählen_rel* and a relation complex that fills the second argument position of the stem's relation. In the given context, the meaning of the prefix is represented by the intersective modifier *falsch_rel* and its modificandum *nummer_rel*.

Taking the procedural view, the E-G processor yields three new input relations when applying this compositional rule. These relations must be processed until the application of terminal TCs terminates.

Other examples of incorporation can be treated in a similar way. (100) shows a nonterminal TC that provides a solution for (96).

(100)

$$\left\langle \begin{bmatrix} \textit{neg\_rel} & \\ \text{HANDEL} & \boxed{4} \\ \text{HD-ARG} & \boxed{5} \end{bmatrix}, \begin{bmatrix} \textit{bestehen\_rel} & & \\ \text{HANDEL} & \boxed{5} & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \textit{exam\_sit\_s} \end{bmatrix} \right\rangle \Rightarrow \left\langle \begin{bmatrix} \textit{durchfallen\_rel} & \\ \text{HANDEL} & \boxed{4} \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

Here, we are faced with a process of recomposition. The expression *nicht bestehen* cannot be translated into *not pass*. It is always lexicalized by English *fail*. Since German has the verb *durchfallen* that displays the same semantic structure as *fail*, the TC in (100) substitutes the semantic representation of *nicht bestehen* by that of *durchfallen*.[36] The yield SL relation gets its translation correspondence by the terminal TC in (101).

[36] This is an example where handels have to be reorganized. It seems that this is an exceptional case. In most cases, handels can be transferred straightforwardly (cf. [Copestake et al., 1995]), e.g. by making use of bilinks, see 4.3.3.

(101)
$$\left\langle \begin{bmatrix} \textit{durchfallen\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{human\_s} \\ \text{ARG3} & \boxed{3} & \textit{exam\_sit\_s} \end{bmatrix} \right\rangle \Leftrightarrow \left\langle \begin{bmatrix} \textit{fail\_rel} & \\ \text{INST} & \boxed{1} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{3} \end{bmatrix} \right\rangle$$

Finally, we exemplify the application of nonterminal TCs by the treatment of *head switching*, as in (102).

(102) Ich komme gern. $\Leftrightarrow$ I like to come.

Here, the meaning of the German modifier *gerne* is anchored in the English modality state of *liking* that corresponds to German *mögen*. The nonterminal TC in (103) provides a monolingual mapping to express the changed meaning distribution.

(103)
$$\left\langle \boxed{4} \begin{bmatrix} \textit{situation\_rel} & & \\ \text{INST} & \boxed{1} & \\ \text{ARG1} & \boxed{2} & \textit{animate\_s} \end{bmatrix} , \begin{bmatrix} \textit{gerne\_rel} & \\ \text{INST} & \boxed{1} \end{bmatrix} \right\rangle \Rightarrow \left\langle \boxed{4} , \begin{bmatrix} \textit{mögen\_rel} & \\ \text{INST} & \boxed{3} \\ \text{ARG1} & \boxed{2} \\ \text{ARG3} & \boxed{1} \end{bmatrix} \right\rangle$$

The German *gerne_rel* modifies a situation relation that involves an animate argument. The nonterminal TC in (103) is a valid correspondence if a *situation_rel* of the specified type is part of the input list. The relational complex is then recomposed into the underspecified situation relation and a relation *mögen_rel* where the situation relation is embedded as a second argument. Both relations have the same highest argument as it is expected in the case of subject control. In our example, the translation goal terminates with the terminal TC for *mögen_rel* and *kommen_rel*. In more complex cases further decompositional steps might be necessary to terminate this head switching TC.

6 Conclusion

In this report we introduced the conception of MinT as a transfer model for the VERBMOBIL prototype. For illustration, we described its functionality by transferring SL MRS representations into TL MRS representations. However, the ideas outlined here, can also be applied to other semantic formalisms, if they allow a hierachically structuring of semantic predicates. Moreover, its application presupposes a unification-based typed-feature formalism with multiple inheritance.

To summarize, MinT can be characterized as follows:

- Unification-based
  Feature structures are typed and combined via the mechanism of unification.

- Declarativity
  Monolingual and bilingual correspondences are described in a strictly declarative way.

- Bidirectionality
  The use of a declarative rule format allows the bidirectional specification of transfer rules, which is desirable for portability and extension.

- Modularity
  All contrastive knowledge is anchored in the transfer module.

- Abstraction
  Transfer at the level of abstract semantic representations allows to specify transfer rules economically, and admits the generator to produce alternative translations.

- Underspecification
  Transfer on underspecified semantic representations allows transfer to preserve ambiguities within a language pair.

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