How to Overcome Translation Mismatches - An Inference Driven Mapping between Meaning Representations

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Abstract

This paper deals with issues that a bidirectional German-Russian machine translation system faces when the meaning of spatial prepositions in these languages does not line up. A uniform representation language is used to define the meaning of spatial prepositions in a language independent way. This formal language makes it possible to compare monolingual meaning representations and allows for the recognition and resolution of translation mismatches.

0. Introduction

The main problem for multi-lingual machine translation (MT) is that "there is no hope of constructing a language IL [interlingua] which is such that translations in all languages map onto a single abstract representation in IL" ([KAY 1991], p. 78). Even if the ambitions of the IL approach are confined to the design of a meaning representation mediating between two languages there are many translation mappings which cannot share the same representation. Because of translation mismatches intra-lingual mappings between IL representations are often inevitable.

There are several ways to solve translation mismatches. [KAMEYAMA 1991] proposes to add or to drop information depending on whether the target language (TL) renders the expression more precise or allows ambiguity not allowed in the source language (SL). The IL approach taken by [BARNETT 1991] appeals to a monolingual language description where translation mismatches are viewed as generation problems. Here the generator includes techniques that assign preferences to a certain way of expressing an assertion and makes use of SL information to guide this assignment.

This paper contributes to the issue of how the translation mapping between non-identical meaning representations can be achieved in an efficient way by preserving language-pair independence in the lexicon. I sketch an approach of an inference driven mapping between monolingual meaning representations and will apply it to the problem of translating between German and Russian spatial prepositions, which are a well-known source of a wide range of translation mismatches. For the locative prepositions considered I propose meaning representations which express the spatial relation between two concrete objects. The representation language for spatial prepositions is based on tools from set-theoretic topology, i.e. objects are represented as sets of spatial points and the relations between them are expressed in terms of inclusion, overlap and connectedness.

The proposed meaning representations for the German and Russian locative prepositions can be used to infer whether the meaning of the target language preposition is identical with, more general or more specific than that of the source language. These correspondences between SL and TL representations are established by use of identity, superset and subset relations between the sets of spatial points expressed in the prepositions' meaning representations. Following basically the ideas of the "Translation-by-Negotiation-Approach" proposed by [KAY 1991] my approach makes explicit how translation mismatches can be recognized and consequently resolved by a "negotiator" which operates on language independent knowledge.

First, I give a survey of some of the translation problems we are faced with. Second, I present the formal representation language and focus more specifically on issues that concern the meaning representation of spatial expressions in the lexicon. Then, I show how the correspondence between

SL and TL representations is established. Finally, I propose a translation model which involves an inference driven mapping between meaning representations and give an idea of the organization of the lexicon with respect to spatial properties of objects and relations between them.

1. The Translation Picture

I consider spatial relations between two concrete objects expressed by the German locative prepositions "in" ('in'), "auf" ('on'), "an" ('on, next to') and their Russian equivalents "v" ('in'), "na" ('on') and "u" ('next to') respectively, as they occur in expressions of the form "der Käse auf dem Tisch" ('the cheese on the table'), where the PP is a modifier which attributes the property of being located "on the table" to the individual "cheese". Furthermore, the localized object (LO) "cheese" is situated with respect to a particular spatial portion of its reference object (RO) "table", namely its top surface, referred to by the preposition "auf" ('on').

With regard to these simple expressions of spatial relations in German and Russian we may distinguish the following types of translation pattern:

I. Equivalence

If two prepositions in different languages share the same meaning they are assumed to be equivalent. The preposition "in" ('in'), for example, captures the same set of interpretations as the Russian preposition "v" ('in'), i.e., the inclusion in an empty as well as in a materially occupied interior. This is shown in the examples (1-2) and (1'-2') respectively:

(1) die Milch in der Flasche

(1') moloko v butylke

('the milk in the bottle')

(2) der Fisch im See

(2') ryba v ozere

('the fish in the lake')

II. Translation mismatches

Translation mismatches involve cases where one language encodes a spatial relation not directly expressible in the other. Here three different kinds can be distinguished:

II. a Generalization

The TL preposition has a *more general meaning* than the SL preposition. E.g., the meaning of the German preposition "auf" ('on'), which refers primarily to the top surface of its reference object, as in (3, 4), and which can be used to refer to a vertical surface only in a very restricted way, as in (5), is covered by the Russian preposition "na" ('on'). But "na" has a wider domain of application. It highlights the contact with any surface of its reference object. This is shown in the examples (3'-8').

(3) das Buch auf dem Tisch

(3') kniga na stole

('the book on the table')

(4) der Schornstein auf dem Dach

(4') truba na kryše

('the chimney on the roof')

(5) der Schweiß auf/an der Stirn

(5') pot na lbu

('sweat on the forehead')

II. b Specification

The differentiation between spatial relations captured in the TL is not expressible in the SL, i.e., the meaning of the SL preposition is expressed by more than one TL preposition. We are faced with a *specification in the TL* which is not made in the SL. If we translate the Russian preposition "na" ('on'), which primarily refers to any surface of its RO, we have to choose between the German prepositions "an" and "auf". Both these prepositions capture this meaning, as can be seen in (6-8). A similar problem arises if we translate "an" ('on', 'next to') into Russian, as in (7-9). Here "na" ('on') is used if there is contact with the RO's surface and "u" ('next to') if the LO is situated in the neighborhood which surrounds the RO. This is shown in (7',8') in contrast to (9'):

(6') pirog na tarel'ke

(6) der Kuchen auf dem Teller

('the cake on the plate')

(7') kartina na stene

(7) das Bild an der Wand

('the painting on the wall')

(8') list'ja na vetke

(8) die Blätter am Ast

('the leaves on the branch')

(9') derevo u doma

(9) der Baum am Haus

('the tree next to the house')

II. c Idiosyncrasies

A language specific idiosyncratic use of a preposition is another reason for a translation mismatch. This problem is widely discussed and most often handled in the cognitive framework of prototype semantics. Cognitive semanticists explain the idiosyncratic use of a preposition by a distinct language specific conceptualization of spatial entities. These ideas are also reflected in MT approaches to locative prepositions [JAPKOWICZ/WIEBE 1991] and [ZELINSKY-WIBBELT 1990]. They represent the preposition's meaning as an idealized spatial relation between spatial entities schematized as volumes, surfaces or points. I treat spatial entities according to the way they appear in our world and not as they may be conceptualized occurring in connection with a certain preposition. Moreover, it does not always seem to be appropriate to think of a surface when the Russian native speaker uses the preposition "na" ('on') for reference to an interior, as in (10', 11'):

(10) Weizen in der Mühle

(10') pšenica na mel'nice

('wheat in *(on)* the mill')

(11) die Maschinen in der Fabrik

(11') stanki na fabrike

('machines in *(on)* the factory')

This use of the preposition "na" ('on'), which is rather productive in Russian, can be explained only historically. With many nouns, particularly with proper nouns as place names, the use of the preposition "na" is determined by linguistic convention. In some cases where "na" is used with a noun which denotes a building, the influence of the institutional reading, which is also expressed by this preposition, accounts for that use. Nowadays the meaning of such an expression is obviously inclusion in an interior without any necessary contact with a surface. On the other hand, it is more reasonable to think of a different conceptualization when the object has an intermediate shape (e.g. between a surface and a container) which may explain this usage of "na". This is shown in (12', 13'):

(12) das Ei in der Pfanne

(12') jajco na skovorotke

('the egg in *(on)* the pan')

(13) der Sportler im Stadion

(13') sportsmen na stadione

('the sportsmen in *(on)* the stadium')

But even if one might be able to explain the use of the Russian "na" discussed above, there is no way to predict which objects in particular can be combined with that preposition. Therefore, objects which are used with a preposition in an idiosyncratic way have to be marked in the lexicon.

2. A formal representation language for spatial relations

In recent years a wide range of approaches to spatial relations has appeared, for example, the prototype semantics approach taken by [HERSKOVITS 1986, LAKOFF 1987] or the two level approach proposed by [BIERWISCH 1988, LANG 1987, HERWEG 1988]. But among the great variety one can find only a few approaches which aim at a formal semantic representation for spatial prepositions, e.g., those taken by [LUTZEIER 1974, MOILANEN 1979] and [AURNAGUE/VIEU 1992].

In contrast to a prototype semantics approach, which puts forward the idea of an "idealized meaning", or a two level approach, which assumes a primitive meaning on a semantic level which is then more finely articulated at a second conceptual level, I define the meaning of a spatial preposition as the disjunction of all its possible interpretations. The relation of the type "LO LOCATIVE PREPOSITION RO" is understood as a relation between spatial entities where the spatial referent of the RO is determined by the preposition and the LO is mapped onto that portion of space which actually participates in the spatial relation.

In order to understand the prepositions' meaning representations I will briefly introduce some formal specifications of the representation language used here. For more details see [BUSCHBECK-WOLF 1993].

Spatial properties of objects, and the relations between them, are expressed in terms of set-theoretic topology. In other approaches, like [AURNAGUE/VIEU 1992], the representation of spatial prepositions is based on connection theory [CLARKE 1981], where spatial entities are regarded as individuals. Here, following [LUTZEIER 1974, MOILANEN 1979], spatial entities are defined as sets of spatial points. Thus, spatial prepositions denote relations between particular subsets of these point sets. These relations are expressed in terms of inclusion, overlap and connectedness.

Now, let me make the following assumptions:

I is a set of concrete objects a, b, c.... $\langle P, \mathcal{N} \rangle$ is the three-dimensional Euclidian space. $\langle P, \mathcal{N} \rangle$ is a metrical and connected topological space.

Let us consider the space P(a) which is taken up by an object "a" in more detail. It is defined in (14).

(14) $P(a) = \{p \in P \mid p \text{ is occupied by } a\}$

$P(a) \subseteq P$

$\forall a \forall b \;\; a, b \in I$:

$(P(a) \neq \emptyset \wedge P(b) \neq \emptyset \wedge P(a) = P(b)) \rightarrow a = b$

Definition (14) says that the space P(a) which is taken up by the object "a" consists of all spatial points which are occupied by that object. P(a) is a subset of the Euclidian space. Furthermore, it is excluded that two objects may occupy the same space.

There are objects, as e.g. cupboards and vases, with respect to which one has to distinguish between the space which is occupied by their material parts, as e.g. by the wood of a cupboard or the porcelain of a cup, and their empty interior, which also belongs to the space these objects occupy. I refer to these spaces with $P_{MAT}(a)$, the set of materially occupied spatial points, and $P_{EMPTY}(a)$, the set of empty spatial points, which are introduced in (15) and (16).

(15) $P_{MAT}(a) = \{p \in P \mid p \in P(a) \wedge$ p is materially occupied by a $\}$

$P_{MAT}(a) \subseteq P(a)$

$P_{MAT}(a)$ is connected in P

(16) $P_{EMPTY}(a) = \{p \in P \mid p \in P(a) \wedge$ p is not materially occupied by a$\}$

$P_{EMPTY}(a) \subseteq P(a)$

The distinction between materially and non-materially occupied spatial points allows one to classify spatial objects in the way, shown in (17) - (19):

(17) $P_{EMPTY}(a) = \emptyset$ and $P_{MAT}(a) \neq \emptyset$

i.e. $P(a) = P_{MAT}(a)$

If an object consists of materially occupied points only, we have a *massive non-hollow body*, as e.g. a stone.

(18) $P_{MAT}(a) = \emptyset$ and $P_{EMPTY}(a) \neq \emptyset$

i.e. $P(a) = P_{EMPTY}(a)$

If P(a) contains only non-materially occupied points, "a" is a *hollow space*, as e.g. a hole.

(19) $P_{MAT}(a) \neq \emptyset$ and if $P_{EMPTY}(a) \neq \emptyset$

i.e. $P(a) = P_{MAT}(a) \cup P_{EMPTY}(a)$

If an object occupies some spatial points materially and some spatial points non-materially, it refers to a *hollow body*, as e.g. a cupboard. In this case the space the object occupies equals the union of its materially occupied space and its empty interior.

The neighborhood of an object, its vicinity $P_{EXT}(a)$, is another region which has to be defined in order to represent prepositions, as e.g. "near", "by" or "next to". As is shown in (20), $P_{EXT}(a)$ is a subset of the topological space which is complementary to P(a) and has a limited extension, because another object cannot be localized with respect to "a" at arbitrary distances. Hence, the distance from any exterior point of "a" to an interior point of "a" should not be smaller than a real number n_a which has to be contextually determined. It depends on the size, the importance and the functionality of "a" and on the spatial configuration of the objects in its neighborhood

(20) $P_{EXT}(a) \subseteq C(P(a)) \subseteq P$

$P_{EXT}(a) = \{p' \in P \mid p' \notin P(a) \wedge \exists p \in P(a)$ such that $d(p, p') \leq n_a\}$

$P_{EXT}(a)$ is connected in P

Another restriction on the localization of an object "g" in the vicinity of "a" concerns the availability of $P_{EXT}(a)$. An object "g" can be situated in $P_{EXT}(a)$ only in that part of space which is not occupied by another object. This leads us to (21) where a subset of the exterior, namely the available exterior $P_{EXT\text{-}AVAIL}(a)$ is defined.

(21) $P_{EXT\text{-}AVAIL}(a) = \{p^\circ \in P \mid p^\circ \in P_{EXT}(a) \wedge \forall b\, (b \in I)\ p^\circ \notin P(b)\}$

$P_{EXT\text{-}AVAIL}(a) \subseteq P_{EXT}(a)$

The remaining exterior is assumed to be non-available for the localization of another object. This is shown in (22).

(22) $P_{EXT\text{-}NONAVAIL}(a) = P_{EXT}(a) \setminus P_{EXT\text{-}AVAIL}(a)$

$P_{EXT\text{-}NONAVAIL}(a) \subseteq P_{EXT}(a)$

Now I define some subsets of the available exterior of an object which one needs for the representation of prepositions, such as "above", "below" or "by". These are in (24) the "available exterior above a" $P_{TOP\text{-}EXT\text{-}AVAIL}(a)$, in (25) the "available exterior below a" $P_{BOTTOM\text{-}EXT\text{-}AVAIL}(a)$ and in (26) the "available exterior extending horizontally to a" $P_{VERT\text{-}EXT\text{-}AVAIL}(a)$. In (23) the distance between the set of points which is occupied by objects "a" and some point p' of the available exterior is defined as the minimum of the distances from any point of P(a) to p'.

(23) $d(P(a), p') = \min_y \{ d(y, p') \mid y \in P(a) \wedge p' \in P_{EXT\text{-}AVAIL}(a)\}$

Then, this distance is given a direction. Here, $d_{+vert}(P(a), p')$ denotes the minimal distance between the object and a point along the vertical directed against gravity, $d_{-vert}(P(a), p')$ stands for this distance directed with gravity and $d_{hor}(P(a), p')$ signifies the distance between the object and a point along the horizontal, which is situated orthogonal to the vertical.

(24) $P_{TOP\text{-}EXT\text{-}AVAIL}(a) = \{p' \in P_{EXT\text{-}AVAIL}(a) \mid d_{+vert} d(P(a), p') > 0 \wedge d_{hor}(P(a), p') = 0\}$

$P_{TOP\text{-}EXT\text{-}AVAIL}(a) \subseteq P_{EXT\text{-}AVAIL}(a)$

(25) $P_{BOTTOM\text{-}EXT\text{-}AVAIL}(a) = \{p' \in P_{EXT\text{-}AVAIL}(a) \mid d_{-vert} d(P(a), p') > 0 \wedge d_{hor}(P(a), p') = 0\}$

$P_{BOTTOM\text{-}EXT\text{-}AVAIL}(a) \subseteq P_{EXT\text{-}AVAIL}(a)$

(26) $P_{VERT\text{-}EXT\text{-}AVAIL}(a) = P_{EXT\text{-}AVAIL}(a) \setminus \setminus (P_{TOP\text{-}EXT\text{-}AVAIL}(a) \cup P_{BOTTOM\text{-}EXT\text{-}AVAIL}(a))$

$P_{VERT\text{-}EXT\text{-}AVAIL}(a) \subseteq P_{EXT\text{-}AVAIL}(a)$

Finally, we need a definition of the object's surface to which such prepositions as "an" ('on') and "auf" ('on') refer. According to definition (27), the surface consists of all materially occupied points s of an object "a", whose neighborhood contains at least one point p' which belongs to the exterior $P_{EXT}(a)$. This definition also predicts that hollow spaces do not provide a surface, since P(a) contains only non-materially occupied spatial points.

(27) $S(a) = \{s \in P_{MAT}(a) \mid \forall N \in \mathcal{N}(s)\ \exists p' \in N\ p' \in P_{EXT}(a)\}$

$S(a) \subseteq P(a)$

The localization of an object "b" on the surface of "a" presupposes the availability of that surface. I call a surface available if it is the boundary of an available exterior. According to their position in space some subsets of the available surfaces can be distinguished: the top surface $S_{TOP}(a)$, the vertical surface $S_{VERT}(a)$ and the bottom surface $S_{BOTTOM}(a)$. This is shown in (28) - (30).

(28) $S_{TOP}(a) = \{s \in P_{MAT}(a) \mid \forall N \in \mathcal{N}(s)\ \exists p' \in N\ \ p' \in P_{TOP\text{-}EXT\text{-}AVAIL}(a)\}$

$S_{TOP}(a) \subseteq S(a)$

(29) $S_{VERT}(a) = \{s \in P_{MAT}(a) \mid \forall N \in \mathcal{N}(s)\ \exists p' \in N\ \ p' \in P_{VERT\text{-}EXT\text{-}AVAIL}(a)\}$

$S_{VERT}(a) \subseteq S(a)$

(30) $S_{BOTTOM}(a) = \{s \in P_{MAT}(a) \mid \forall N \in \mathcal{N}(s)\ \exists p' \in N\ \ p' \in P_{BOTTOM\text{-}EXT\text{-}AVAIL}(a)\}$

$S_{BOTTOM}(a) \subseteq S(a)$

Summarizing the introduced spatial regions, figure 1 exemplifies some of them for a vase.

3. Meaning representations for spatial prepositions in the lexicon

Now I will use the defined spatial regions to describe the meaning of locative prepositions. It should be mentioned that the application to the domain of machine translation imposes certain constraints on the depth of the prepositions' meaning representations. They have to capture all the distinctions made in the languages involved. But to push the analysis beyond that would only slow down the system. Here I will basically make use of topological representations to capture the meaning of the spatial prepositions. For the prepositions considered functional relations are ignored since they do not influence the choice of a TL preposition. In most cases they are obvious from the spatial configuration between the involved objects. Here the meaning of a spatial preposition is represented fully independently of any TL requirements. It is the disjunction of all its possible interpretations. The relation of the type "a PREPOSITION b" where "a" is the LO and "b" the RO is valid if and only if one of the possible representations is true.

The German preposition "in" ('in') is represented in (31):

(31) a IN b $\Leftrightarrow$ (a) $P(a) \subset P_{EMPTY}(b)$

(b) $P(a) \subset P_{MAT}(b)$

"In" provides two distinct interpretations. On the one hand the (31a) clause says that the space occupied by the LO is contained in the empty interior of the RO (cf. ex. 1). On the other hand (31b) accounts for the inclusion of the space which is taken up by the LO in the materially occupied interior of the RO (cf. ex. 2).

The representations in (31) cannot cope with the partial inclusion in an empty or in a materially occupied interior, i.e. no truth-value can be assigned to expressions of the type "the flowers in the vase" or "the nail in the board". I will skip the definition of partial inclusion here, since it is not essential to further considerations. The preposition "auf" ('on') has a more complex interpretation, as can be seen in

(32) a AUF b $\Leftrightarrow$

(a) $S(a) \circledcirc S_{TOP}(b)$

(b) $(P(a) \cap P(b)) \subset S_{TOP}(b)$

(c) if "a" is a thin surface-like object:
$S(a) \circledcirc S_{VERT}(b)$

(d) if "b" is used idiosyncratically with "auf":
$P(a) \subset P_{EMPTY}(b)$

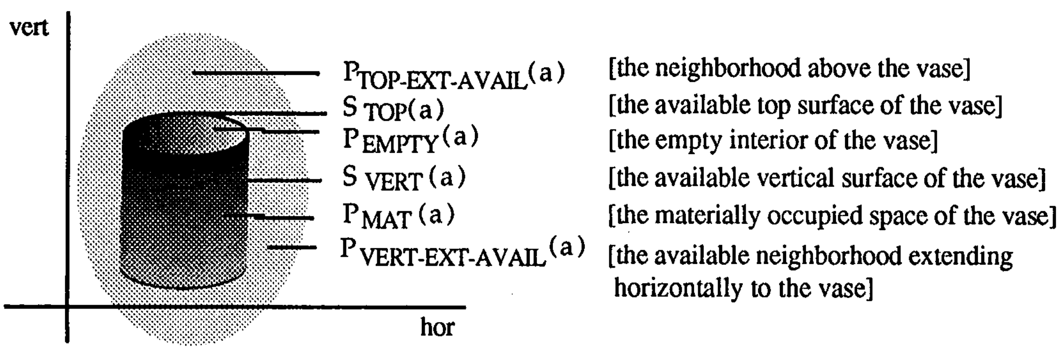

figure 1

According to (32a) the preposition "auf" expresses that the surface of the LO is in contact with the top surface of the RO (cf. ex.3, 6). The topological property of connectedness can be used to describe the contact relation between two surfaces. Here the notation "©" expresses that the union of the particular surfaces is connected. (32a) is the default reading of "auf". It presupposes the existence of a vertical direction and of gravity. Hence, the functional relation of support could easily be derived from the given spatial configuration. The (32b) clause says that the intersection of the material interior of the objects involved is contained in the top surface of the RO. This abstraction should capture the "embedding" of the LO in the top surface of the RO (cf. ex.4). (32c) describes the homogeneous contact of the surface of the LO with the vertical surface of the RO. The use of "auf" for the reference to a vertical surface is restricted to thin surface-like objects or liquid and granular substances in the role of the LO and to ROs which provide a salient vertical surface (cf. ex.5). Finally, (32d) shows that "auf" can also be used to highlight the empty interior of its reference object. Again this use is restricted to a couple of objects and cannot be predicted (cf. die Lampe auf dem Flur ('the lamp in *(on)* the hall')).

Now let us look at the spatial meaning of the preposition "an" ('on', 'next to') in (33):

(33) a AN b $\Leftrightarrow$ (a) $S(a) © S_{VERT}(b)$

(b) $(P(a) \cap P(b)) \subset S(b)$

(c) if "b" is a strictly bounded object:

$P(a) \subset P_{VERT\text{-}EXT\text{-}AVAIL}(b)$

In (33a) "an" captures the contact of a surface of the LO with the vertical surface of the RO (cf. ex. 5, 7). Representation (33b) denotes that the LO is an appendage of the RO which is embedded in its surface (cf. ex.8). This representation overlaps with (32b). In the generation process (33b) is assumed to be the default interpretation, if we can exclude the embedding in a top surface denoted by (32b), since the more specific representation is given preference. Under (33c) "an" says that the LO is situated in the available exterior of the RO, which extends horizontally to it. It is valid only if the RO is a strictly bounded object (cf. ex.9).

Now I turn to some Russian locative prepositions.

First, the meaning of "v" ('in) is represented in (34). It captures exactly the same set of interpretations as the German preposition "in" does, (cf. ex. 1'- 2').

(34) a V b $\Leftrightarrow$ (a) $P(a) \subset P_{EMPTY}(b)$

(b) $P(a) \subset P_{MAT}(b)$

As we can see in (35) the Russian locative preposition "na" ('on') has a wider reading:

(35) a NA b $\Leftrightarrow$

(a) $S(a) © S(b)$

(b) $(P(a) \cap P(b)) \subset S(b)$

(c) if "b" is idiosyncratically used with "na":

$P(a) \subset P_{EMPTY}(b)$

As shown in (35a) "na" expresses the contact of the LO's surface with any surface of its RO (cf. ex. 3', 5', 6', 7'). The (35b) clause says that a part of the LO is embedded in the RO's surface (cf. ex.4', 8'). The third meaning (35c) captured by "na" is its reference to an empty interior, which is valid only for lexically marked objects (cf. ex.10'-13').

Finally, representation (36) indicates that the Russian preposition "u" ('next to') is used to situate an object in the available neighborhood of the RO which extends horizontally to it (cf. ex.9').

(38) a U b $\Leftrightarrow$ $P(a) \subset P_{VERT\text{-}EXT\text{-}AVAIL}(b)$

4. The correspondences between source and target language representations

Now let us apply the introduced meaning representations for spatial prepositions to the domain of machine translation. Assuming that the given complex meaning representations are present in the SL lexicon, it is the task of the analysis to find out which of the possible interpretations is appropriate. The question arises whether it is always necessary to disambiguate the given representations. If we look at the translation picture in section one, it turns out that the translation mapping can be guided by TL requirements. In the case where the SL representation is completely shared by a TL preposition (I. equivalence) the mapping is straightforward. If the meaning of the SL preposition is a submeaning of a TL preposition (II.a generalization) then the more general TL representation is the appropriate one. If the TL makes a distinction not made in the SL (II.b specification), an analysis is indispensable, and must go as deep as the TL specification. If the use of the TL preposition is idiosyncratic (II.c idiosyncrasy) then the mapping is justified if the corresponding RO is appropriately marked in the lexicon.

In order to find out the correspondence between source and target language representations each disjunct of the given SL representation is compared with TL representations in the TL lexicon. We have to find those from which the appropriate TL preposition can be derived. These are TL representations which are identical with one of the given SL representations or which share partially at least one of those. Here knowledge about the sets of spatial points described in the prepositions' meaning representations is used to infer (i) which are the corresponding TL representations and (ii) which relation holds between the SL and TL representations. This relation points out the kind of translation mismatch. Consequently, it suggests the appropriate mapping level. More precisely, if the set of spatial points of the RO expressed in the TL representation is a *superset* of the one expressed in the SL representation, and the remaining parts of the SL and TL propositions are identical, then we are faced with a *generalization in the TL.* Here the translation mapping is allowed since the SL representation logically implies the TL representation. If the set of spatial points the RO in the TL refers to is a *subset* of the set the RO in the SL refers to, then a *specification in the TL* is recognized. If there is more than one such TL representation from which different prepositions can be derived, no mapping can be carried out. An analysis according to the TL specification is then indispensable.

Hence, the correspondences between SL and TL representations are inferred on the basis of identity, superset and subset relations between the sets of spatial points described in the prepositions' meaning representations. Let me illustrate this with some examples. We want to translate the German preposition "auf" into Russian. It is replaced by the expressions (32a-d):

(32a) $S(a) © S_{TOP}(b)$

(32b) $(P(a) \cap P(b)) \subset S_{TOP}(b)$

(32c) if "a" is a thin surface-like object:
$S(a) © S_{VERT}(b)$

(32d) if "b"is used idiosyncratically with "auf":
$P(a) \subset P_{EMPTY}(b)$

Here the following TL representations are picked out as the corresponding ones:

(35a) $S(a) © S(b)$

(35b) $(P(a) \cap P(b)) \subset S(b)$

(35c) if "b" is used idiosyncratically with "na":
$P(a) \subset P_{EMPTY}(b)$

(34a) $P(a) \subset P_{EMPTY}(b)$

These representations are found in the following way.

Given (28) $S_{TOP}(a) \subseteq S(a)$ it can be inferred that (32a) is a submeaning of (35a), and (32b) is a submeaning of (35b). If it turns out that the German LO fulfills the condition on meaning (32c), then according to (29) $S_{VERT}(a) \subseteq S(a)$ (32c) is a submeaning of (35a). Moreover, if the German RO is used with the preposition "auf" to refer to an empty interior (32d), then (35c) and (34a) are the corresponding representations because of the identity relation. Here the lexical information on the Russian RO is decisive for the choice between "v" ('in') or "na" ('on') in the TL. If one of the remaining representations (32a-c) is valid the mapping is also straightforward, because the set to which the target language RO refers is a superset of that to which the RO in the SL refers. The superset relation suggests a generalization in the TL, i.e., an analysis is not necessary. Consequently, the mapping to the more general representations (35a,b) is allowed and the Russian preposition "na" is generated.

Now let us consider a more complicated case, the translation of the Russian preposition "na"('on'), which has the following meaning:

(35a) $S(a) © S(b)$

(35b) $(P(a) \cap P(b)) \subset S(b)$

(35c) if "b" is idiosyncratically used with "na":
$P(a) \subset P_{EMPTY}(b)$

In this case a lot of corresponding representations are found:

(32a) $S(a) © S_{TOP}(b)$

(32b) $(P(a) \cap P(b)) \subset S_{TOP}(b)$

(32c) if "a" is a thin surface-like object:
$S(a) © S_{VERT}(b)$

(32d) if "b" is used idiosyncratically with "auf"
$P(a) \subset P_{EMPTY}(b)$

(33a) $S(a) © S_{VERT}(b)$

(33b) $(P(a) \cap P(b)) \subset S(b)$

(31a) $P(a) \subset P_{EMPTY}(b)$

These TL representations are picked out in the following way. On the one hand (35a) includes (32a) and (35b) includes (32b) since (28) $S(a) \supseteq S_{TOP}(a)$. On the other hand, given (29) $S(a) \supseteq S_{VERT}(a)$, it can be inferred that (32c) and (33a) are contained in (35a). (35b) and (33b) are identical. In the case of appropriate lexical information on the Russian RO, (35c) is identical with (31a) and with (32d) if the German RO is also used idiosyncratically.

Here the mapping is allowed only if the Russian RO makes an idiosyncratic use of the preposition "na" (35c). In this case no other SL interpretation is valid since the idiosyncratic use is always given preference. Because of the identity relation the mapping can be processed. Comparing the remaining SL and TL representations a specification in the TL can be inferred because the sets to which the target language ROs refer are subsets of that to which the ROs in the SL refers. From the found TL interpretations two different prepositions, namely "auf" and "an", can be generated, i.e., the translation mapping cannot be processed.

The analysis has to show which of the TL representations is the appropriate one in the given situation. This is done using knowledge about the spatial properties of the RO and the functional relations between the two objects involved.

5. The translation model

How can these ideas be realized in a MT model? Following basically the ideas of the "Translation-by-Negotiation-Approach" proposed by [KAY 1991], a translation model which makes use of the introduced meaning representations and the inference guided mapping between them is represented diagrammatically in figure 2.

Ignoring the syntactic analysis, first the preposition is replaced by the disjunction of all its possible meanings. On this level no analysis is carried out to find the appropriate one among the possible SL interpretations. The whole bundle of possible meanings is sent to the negotiator. The latter finds all representations in the TL lexicon from which a corresponding preposition can be derived. If only identical representations are found or if all corresponding TL representations have a more general meaning, then the mapping is straightforward (M1). In the case of an idiosyncratic use of the SL or TL preposition the mapping is determined by the lexical information of the corresponding RO. If the negotiator finds only more specific TL representations, from which different prepositions are generated, the analysis must go as deep as the TL specification requires. If one of them is found the mapping (M2) is carried out. Then, the TL preposition is generated from the appropriate TL representation.

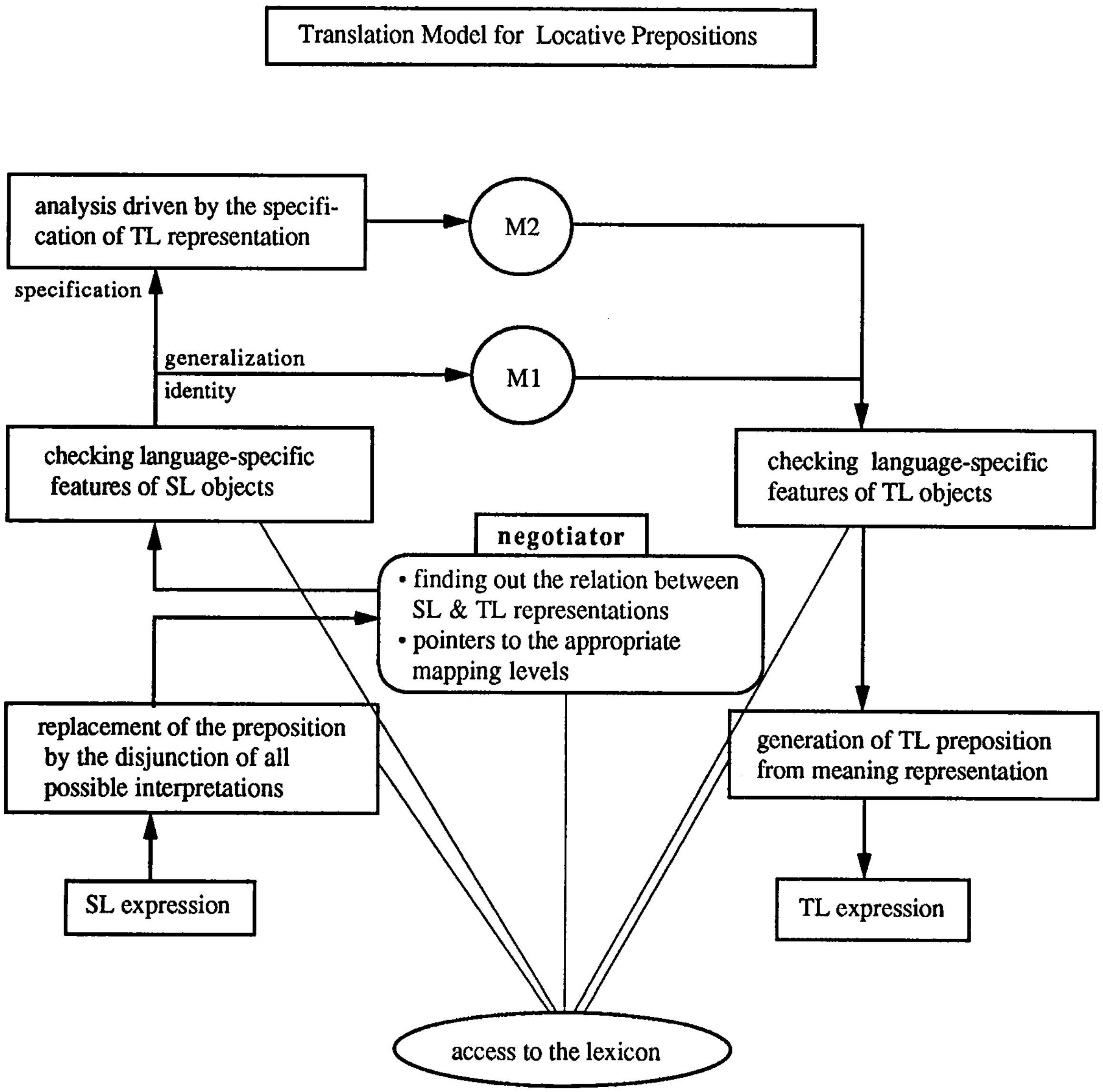

figure 2

6. The lexicon

The defined spatial regions (see section 2) allow one to describe and to classify spatial objects. The ontology found here reflects above all the topological properties of objects, which are relevant for the locative prepositions considered in this investigation.

Without going into detail I want to give some of the classificational criteria used in the ontology of three-dimensional objects. One of them is the distinction based on the composition of the space the object occupies (for definition see (18) - (20)). If it consists of materially occupied points only, then either a non-hollow massive object, as e.g., a brick or a lake, or a substance, as e.g., water or wood, is concerned. If an object consists of exclusively non-materially occupied points, then it refers to a hollow space, as e.g., a cave or a ditch. If an object takes up materially as well as non-materially occupied spatial points, then it is either a hollow body, as for example, a cup or a bus, or a group of objects, as e.g., a forest or a town, where the hollow space is created by the space between the particular members of the group. Moreover, whether hollow bodies and hollow spaces are closed or open is decisive. Other classificational criteria concern the available surface of the object, its boundedness, its canonical position according to the earth's surface and its typical neighborhood.

The ontology allows the description of topological properties of objects as properties of a whole class. This makes possible an efficient spatial description of objects in the lexicon. A lexicon applicable to a MT model is shown in figure 3.

Under the condition that a noun in both languages denotes the same object in the world, an identical spatial referent can be assumed. In this case the spatial features can be shared by SL and TL objects in a common part of the lexicon. Language specific information, such as the meaning of the locative prepositions and the idiosyncratic use of prepositions are stored separately.

Lexicon

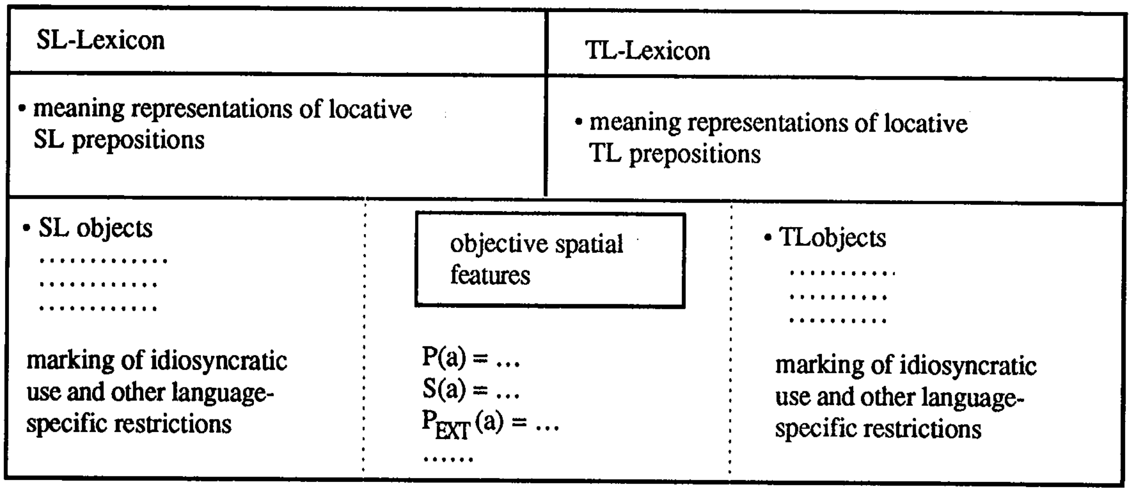

figure 3

7. Conclusion

In this paper meaning representations for German and Russian spatial prepositions have been proposed. Considering the translation phenomena of identity, generalization, specification and idiosyncrasy, it was shown that the underlying formal representation language makes it possible to find out the actual relation between SL and TL representations and to determine the appropriate mapping level. This way the mapping is carried out at a level as shallow as possible and the depth of analysis is restricted to the necessary amount.

Hence, if an appropriate representation language is used it is possible to mediate between non-identical meaning representations so that we can get by with a monolingual description maintaining the language-independence assumption. This way the difficulties of finding an abstract representation of thought, which is shared by the languages involved, can be avoided.

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