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FROM MEANING TO TEXT AND FROM MEANING TO MEANING: TRANSDUCTION AND TRANSFORMATION IN THE MEANING-TEXT THEORY

For Igor, who taught me curiosity and enthusiasm for the marvels of language

A b s t r a c t. The linguistic models of the Meaning-Text Theory (MTM) have always been defended as an exclusively «equative» or «translative» device. However, while, formally speaking, translation is the appropriate means for mapping a structure at a given level of the MTM to its corresponding structure at the adjacent level, it is not so for paraphrasing of a given structure or the composition of a well-formed structure. For both, transformation devices are much more appropriate. Therefore, we argue for the extension of the MTM by such devices for paraphrasing and composition. Our argumentation is not new; some works on how to handle transformation and composition in an MTM already exist. Still, and despite these works, transformation has a negative connotation in MTT. We attempt to show that this is not justified and that transformation has also a say in MTT.

K e y w o r d s: Meaning-Text Theory, Meaning-Text Model, translation, transformation, transition, paraphrase, composition

1. Introduction

One of Igor Mel'čuk's most categorical assertions with respect to the models of the Meaning-Text Theory (MTT) is that «The MTM is by no means a generative or, for that matter, transformational system: it is a purely EQUATIVE (or translative) device» (Mel'čuk 1988a: 45). This is certainly true when we consider what most of the practitioners of MTT would perceive as the «core mission» of the MTT, and what is signaled by the correspondence $\{SemR_i\} \Leftrightarrow \{PhonR_j\}$ used to express the sequence of the projections of the structures between adjacent levels of the MTM. However, this assertion leaves aside two important aspects that equally have their very right of existence within the MTM: (i) paraphrasing and (ii) composition of well-formed structures at the different levels of the MTM. Paraphrasing has indis-

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putably been an integral part of the MTM since its early years. Thus, a deep-syntactic paraphrasing model that is based, first of all, on lexical functions (LFs) has been presented by I. Mel'čuk, for instance, in (Mel'čuk 1974; 1988b; 1992). Semantic paraphrasing models have been proposed by J. Apresjan and L. Cinman (1998; 2002) and J. Milićević (2007) — the first again based on LFs. The issue of the composition of well-formed structures in MTT has been broached in explicit terms by Gladkij and Mel'čuk (1971), but since then did not receive much attention in the MTT-literature, except for the works, first of all, by S. Kahane and F. Lareau (Kahane, Mel'čuk 1999; Kahane 2004; Kahane, Lareau 2005; Lareau 2007). Thus, in the main- stream MTT, it is largely still the linguist «del turno» who has to decide, resorting to his competence, whether a given linguistic structure is well-formed. Hardly any formal implementable means to verify it are available! [1] While this may be sufficient for a descriptive theory used for an exemplary outline of the linguistic apparatus of a language, it is not sufficient for a theory that serves as basis for a variety of computational applications, including text synthesis, text analysis, and machine translation as MTT does: we need to be able to *prove* in each case that a given structure is well-formed.

Both paraphrasing and structure composition are in their nature transformative (Gladkij, Mel'čuk 1983). Therefore, we need to view transformation as the second basic operation of the MTT model. To disregard transformation would mean to limit the scope of the MTM and would not do justice to the theoretical and practical proposals which have already been worked out under the banner of MTT. This demand is by no means revolutionary. Its theoretical seeds can be found in earlier publications that form the foundations of the MTT; see, for instance, (Gladkij, Mel'čuk 1971; 1983; Mel'čuk 1974). In a number of works, transformation in MTM is also taken for granted, although without that the assertion of its «non-existence» would have been revised (Mel'čuk 1992; Apresjan, Cinman 2002; Kahane 2004; Kahane, Lareau 2005; Milićević 2007). Therefore, we feel that it is time that we lift the ban on transformation and assign it the proper place that it deserves in the MTM. This short essay is an attempt to make the first step into this direction.

2. Linguistic processes in an MTM

As already mentioned above, an MTM must account for three linguistic processes:

1. *Creation of a well-formed representation at any level* S *of the MTM.*

We must be able to construct, applying explicit criteria that guarantee its well-formedness, a representation that encodes the intended meaning and form at any of

[1] In the ETAP-system, rules to verify the well-formedness of syntactic structures are available (Iomdin, personal communication).

the levels of the MTM — as, for instance, the Deep-Syntactic Structure (DSyntS) for the sentence (1) in Figure 1 [2].

(1) *This year, Igor received a valuable present from his friends in Moscow for his birthday.*

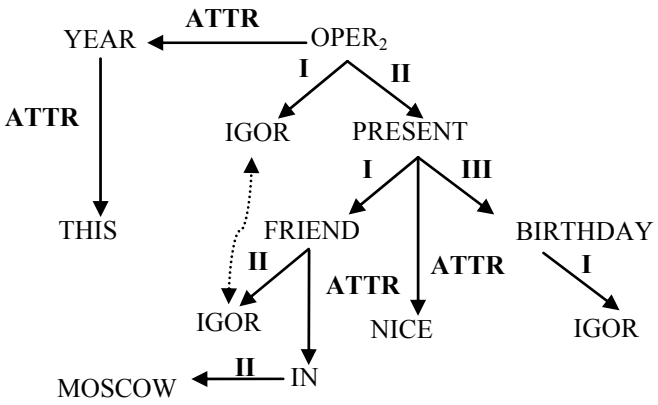

Figure 1: Deep-syntactic structure for (1)

Furthermore, we must have the means to verify (automatically) whether a given representation is well-formed. As pointed out in the Introduction, discussion of composition in MTT in explicit terms has been avoided for a long time. One can hypothesize that this is because, on the one hand, linguists who work in MTT know how to draw a well-formed structure and can verify easily whether a given structure is well-formed (and thus do not feel the need of a formal proof model or an aid that would support correct composition). On the other hand, computational linguists so far worked with MTT in applications in which well-formed structures are either in the input or output of the program, so that, again, no need was perceived for a structure verification program.

Still, it would be incorrect to say that no work on composition has been done in MTT. Thus, the numerous descriptive works on different aspects of languages, as, e.g., (Mel'čuk, Pertsov 1987) on the surface syntax of English, (Mel'čuk 1988a) on the surface syntax of Alutor, (Iordanskaja, Mel'čuk 2009) on the surface syntax of French, (Beck, Mel'čuk 2011) on the morphology of Totonac, and (Burga et al. 2011) on the surface syntax in Spanish — to name just a few — are, in fact, works on composition, even if they do not say so explicitly.

[2] We presuppose a certain familiarity of the reader with the Meaning-Text Theory and thus do not introduce the basic notions of the Theory and its Model.

2. *Mapping of a well-formed structure S at the level S onto its corresponding structure S′ at the level S_{i+1} or at the level S_{i-1}, respectively.*

The components with the grammars of the mappings between structures of the adjacent levels of the MTM form the backbone of the MTM. They are, so to speak, the trademark of the MTT and do not need further elaboration or justification. Significant bodies of work on the different components are available, also thanks to computational implementations in the framework of machine translation (Apresjan et al. 1992), parsing (Nasr 1996) and synthesis (Wanner et al. 2010; Bouayad-Agha et al. 2012a; 2012b). Just for illustration, consider in Figure 2 the mapping of the DSyntS of (1) onto the corresponding Surface-Syntactic Structure (SSyntS).

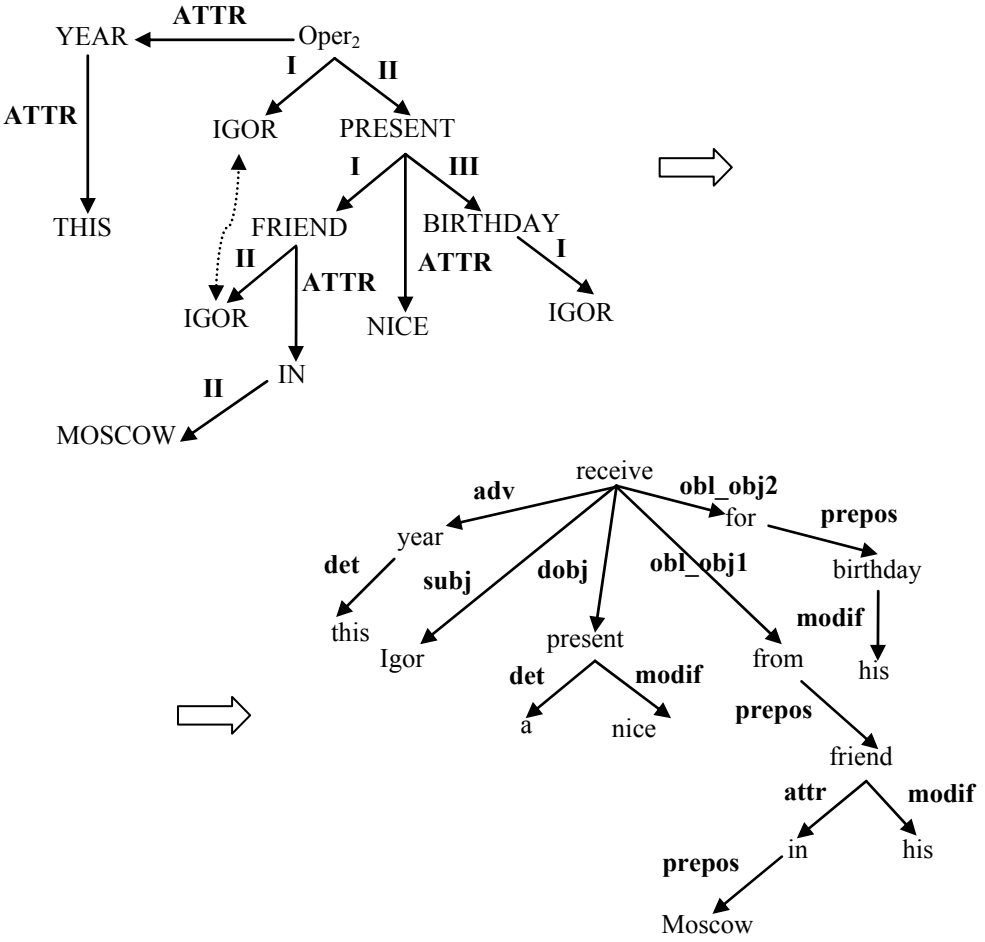

Figure 2: Mapping of the DSyntS of (1) onto its corresponding SSyntS

3. *Paraphrasing of a well-formed structure S at the level* **S** *into an equivalent structure S′ at the same level* **S**.

Paraphrasing has equally been widely discussed and worked on in MTT. Figure 3 illustrates the paraphrasing of the DSyntS of (1) as DSyntS of (2).

(3) *This year, Igor's friends in Moscow sent him a valuable present for his birthday.*

The basic difference between the two DSyntSs is the use of an $Oper_2$ in the first and of an $Oper_1$ in the second.

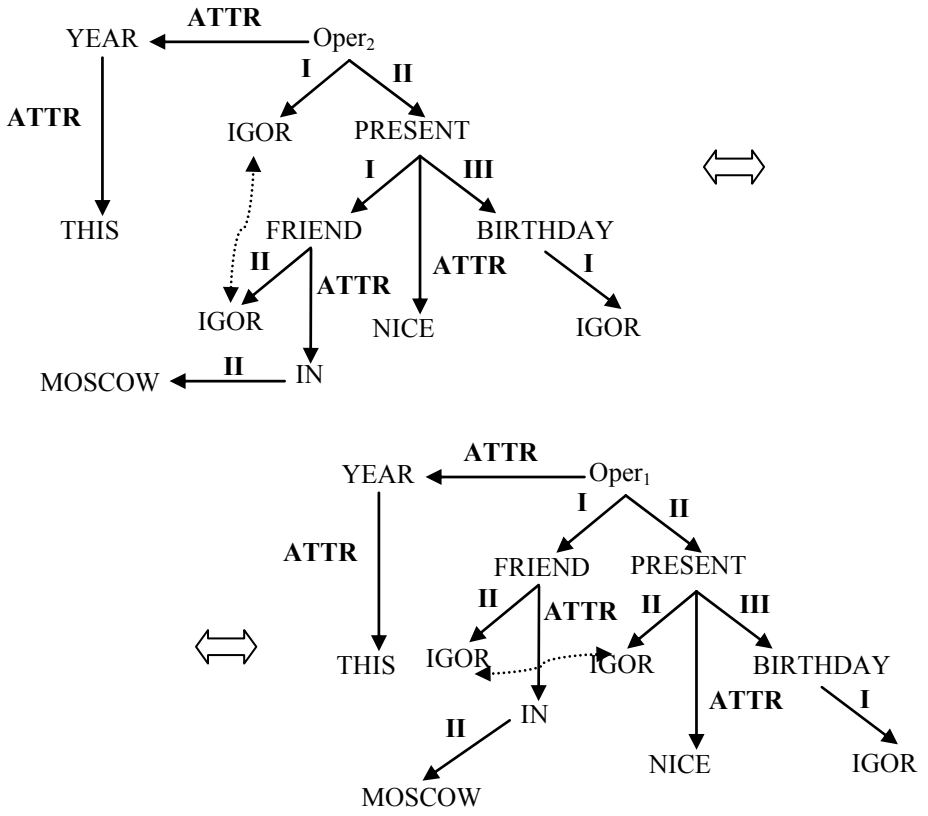

Figure 3: Two equivalent DSyntSs

We already mentioned in the Introduction the LF-paraphrasing model by I. Mel'čuk and the semantic paraphrasing model proposed by J. Milićević. Particularly interesting in the context of paraphrasing is the work carried out by J. Apresjan and colleagues on the extension of Mel'čuk's model and its large cov-

erage implementation (Apresjan, Cinman 2002; Apresjan et al. 2009). It is in working, stable large coverage systems that we see the value of our theoretical models.

3. On translation and transformation and their use in an MTM

In order to implement the above three linguistic processes (composition, mapping, and paraphrasing), we need to look at them from a more formal point of view. Let us focus, in what follows, on the latter two: mapping and paraphrasing. As already mentioned in the Introduction, composition has been discussed by S. Kahane and F. Lareau, so we can leave it aside in this short essay.

Two major formalisms can be used for structure mapping and structure paraphrasing, that of translation and that of transformation. So far, MTT showed a strong preference for translation. Let us have a look at the nature of both, but before we go any further, we need to define first what we mean by *translation* and *transformation*.

3.1. Basic Definitions

Definition 1: Operation of *Translation* (T_l)

Given a well-formed source structure S_s at the MTM stratum $\mathcal{S}$, S_s is said to be translated into a well-formed target structure S_t at the MTM stratum $\mathcal{S}'$, if the following conditions hold:

(i) S_s and S_t are semantically equivalent;
(ii) S_s can be accessed in its entirety at any moment of the operation;
(iii) a static correspondence holds between (substructures of) S_s and (substructures of) S_t.

The condition (ii) means that to obtain S_t, S_s is not modified at any time during the translation; the condition (iii) captures that when a substructure $S_{t.i}$ of S_t is introduced as translation of a substructure $S_{s.j}$ of S_s, a correspondence can be established between the elements of $S_{t.i}$ and $S_{s.j}$ and this correspondence is not changed, i.e., is static, later on (e.g., to adjust $S_{t.i}$ in S_t).

In accordance with Definition 1, translation possesses the following five fundamental features:

1. it is meaning preserving: the target structure S_t does not change the meaning of the source structure S_s.
2. it is structure conserving: it keeps the source structure S_s intact;
3. it is (formal) language observing: at no time, an intermediate structure is created which would contain elements of both S_s and S_t; [3]

[3] An explanatory remark is in order here: The representations at each level of the MTM are defined over distinct vocabulary and relation label alphabets, following rules that

4. it is parallel in its nature: in principle, any set of rules that translate distinct fragments of S_s can be executed simultaneously; [4]
5. it facilitates the use of an extended context at both the source side and the target side in terms of conditions: when mapping a fragment of the source structure, we can always access the rest of the source structure and that part of the target structure which has already been created as context in which the translation must take place.

The last four features are characteristic of *transduction* (see Antworth 1991; Bohnet 2006). In principle, translation can be also realized by *equative* or *generative* grammars (Kahane 2001), however, it is undisputed in the MTT-community that it is best captured by transduction. For a presentation of a large coverage operational multilingual text synthesizer that is based on Bohnet's model and that has already been used in a series of applications, see, e.g., (Wanner et al. 2010; Bouayad-Agha et al. 2012a; 2012b).

Definition 2: Operation of *Transformation* (T_f)

Given a well-formed structure S_s at the MTM stratum $\mathcal{S}$, S_s is said to be transformed into a well-formed structure S_t at the MTM stratum $\mathcal{S}'$, if the following conditions hold:

(i) S_s and S_t are semantically equivalent;
(ii) $S_t = T_f(\ldots T_f(T_f(T_f(S_s)))\ldots)$, i.e., to obtain S_t from S_s, a sequence of intermediate structures is ran through: $S_s \Rightarrow S_1 \Rightarrow S_2 \Rightarrow \ldots S_{n-1} \Rightarrow S_t$;
(iii) the correspondence between substructures of S_s and S_t is conditioned by the order of the execution of the individual steps of the operation.

In accordance with Definition 2, transformation possesses the following four fundamental features:

1. it is meaning preserving: S_s and S_t are semantically equivalent;
2. it is structure rewriting: it modifies (rewrites) the source structure S_s into the target structure S_t by substituting fragments of S_s by fragments of S_t and by possibly making after the substitution further structural adjustments to make S_t well-formed;
3. it is potentially «multilingual»: if S_s is defined in another (formal) language than S_t (i.e., if S_s and S_t belong to different levels of the MTM), the

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are specific to each level. We can thus say that each level $\mathcal{S}$ is characterized by a distinct (formal) language $\mathcal{L}_{\mathcal{S}}$ in which its representations are written. «Language observing» thus means in this context that no structure is produced that would mix the languages such that one fragment of it would be written in $\mathcal{L}_{\mathcal{S}}$ and another in $\mathcal{L}_{\mathcal{S}+l}$.

[4] Obviously, a sequentialization of the rules can be enforced by introducing context conditions that draw upon already created parts of the target structure.

substitution of a fragment of S_s by a fragment of S_t will result in an S_i which contains fragments in the languages of both languages;

4. it is sequential in its nature: a rule applied to S_i is not necessarily applicable to S_{i-1}.

With the definitions and features of translation and transformation at hand, let us examine which of them is more suitable for mapping and paraphrasing in an MTM.

3.2. $\mathcal{S}_i \Rightarrow \mathcal{S}_{i+1}$ Mapping in an MTM

It seems clear that the mapping of a given structure S_s defined at the stratum $\mathcal{S}_i$ to its corresponding structure S_t at the stratum $\mathcal{S}_{i+1}$ (with i = semantic, deep-syntactic, surface-syntactic, deep-morphologic) is best described by translation and thus transduction. Transduction reflects best the stratificational nature of an MTM in which the structures at each level are written in distinct languages defined over distinct alphabets. Transduction can be modeled as a two-tape automaton in which S_s is represented on the input tape and S_t is created on the output tape. The automaton reads the input tape (and, in case it accesses as context the already created substructures of S_t also the output tape) and writes on the output tape fragments of S_t, depending on what it reads. During the reading procedure, no changes are made to the structures which are read.

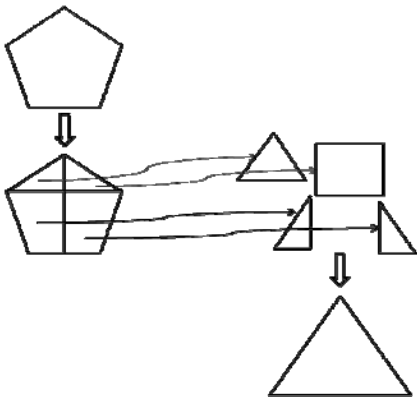

Figure 4: The operation of mapping in an MTM

Figure 4 illustrates the operation of mapping. Thus, to translate the DSyntS of the sentence (1) into its corresponding SSyntS (see Figure 2), individual rules transduce the node $Oper_2$ into *receive*, the arc YEAR ←ATTR–$Oper_2$ into *year* ←adv–*receive*, and so on, until all fragments of the DSyntS have their correspondence in the target SSyntS and we thus obtain a forest of SSynt nodes and arcs. Af-

ter that, the individual nodes and the arcs of the forest are unified into a connected well-formed structure. Outlines of formal transduction grammars for an MTM can be found, for instance, in (Kahane 2000) and (Bohnet 2006).

Note that transduction is not the only option we have in order to realize the inter-level structure mapping; see, for instance, (Chevreau et al. 1999) for a transformation-based mapping.

3.3. Paraphrasing in MTT

In paraphrasing (be it semantic or deep-syntactic), a fragment F_1 of a given structure S_s is substituted by its equivalent F_2, such that the resulting structure $S_t = (S_s / F_1) \cup F_2$, possibly after a number of following structural adjustments, is a well-formed structure that is equivalent to S_s. Both S_s and S_t belong to the same level in the MTM ($\mathcal{S} = \mathcal{S}'$) such that S_s and S_t are defined over the same alphabets, following the same composition rules and well-formedness criteria. The natural description of paraphrasing is by means of transformation; see Figure 5 for illustration. For instance, to paraphrase the DSyntS of (1) as DSyntS of (2) as shown in Figure 3, first, the lexical paraphrasing rule (38) in (Melčuk 1992: 41), $\text{Oper}_1(\text{PRESENT}) \Leftrightarrow \text{Oper}_2(\text{PRESENT})$ is applied to the DSyntS of (1), then to the obtained intermediate structure, the auxiliary structural rules (21) and (12) in (Mel'čuk 1992) are applied (again in sequence). Once the rephrasing is done, the obtained subtree is connected with the remainder of the DSyntS of (1) from which the Oper_2-construction has been removed.

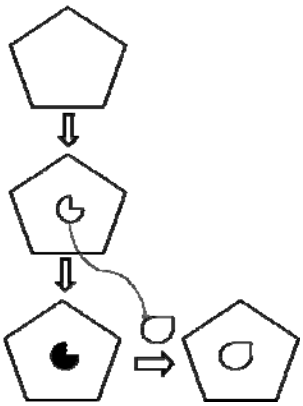

Figure 5: The operation of paraphrasing in an MTM

From the formal point of view, it is not reasonable (although possible) to model paraphrasing as an equative or translative device: paraphrasing usually af-

fects only a fragment of the source structure, so that a translation would result in the need to copy one-to-one the non-affected parts of the structure to obtain a complete target structure (see the definition of translation above) — a procedure that lacks both theoretical and practical justification. Thus, we would first obtain at the target side IGOR ←II–FRIEND ←I–$Oper_1$(PRESENT) –II→PRESENT [5]. In order to arrive at the DSyntS of (2), which also includes *this year*, *in Moscow*, and *nice*, we would thus need to «translate» the remainder of the DSyntS in Figure 1 as well in order to bring it to the target side.

Obviously, it can be argued that what is appropriate is «local translation» (or better: «equation») of the fragment that is to be paraphrased into its paraphrase; with the rest of the structure remaining untouched. However, the following observations speak against this argumentation:

— the local translation does not lead to structure preservation, as required by translation in general: the source structure is "consumed" during the process;
— the local translation operations are necessarily sequential (contrary to what is required by translation in general); thus, in the paraphrasing example above, we literally rewrite the obtained $Oper_1$-construction by the auxiliary structural rules until we reach the well-formed DSyntS of (2).

To the best of our knowledge, the paraphrasing system described in (Apresjan, Cinman 1998; 2002; Apresjan et al. 2009) is equally based on transformation.

4. Towards an extended MTM

We are all used to picturing the MTM as a series of bidirectional transition mappings between adjacent levels. However, the more realistic picture that reflects the other two basic linguistic processes in an MTM, namely paraphrasing and composition, is somewhat more complex. It is depicted in Figure 6 below for written language [6]. Thus, apart from the «vertical» mapping components, we must incorporate the «horizontal» components of paraphrasing and composition, and while the vertical components are realized by means of transduction grammars, the horizontal components are realized in terms of transformation grammars.

A transduction grammar $G_{S_i\text{-}S_{i+1}}$ is defined over structures of two strata S_i and S_{i+1}. Its rules translate minimal parts (i.e., labeled vertices and labeled arcs) of any well-formed structure S_s of the stratum S_i into substructures of the stratum S_{i+1}, which are then unified into a well-formed structure S_t of S_{i+1}.

[5] The rules in (Mel'čuk 1992) tend to be underspecified in that they do not determine how the target substructure is to be connected with its context.

[6] We also include only those paraphrasing components that have been worked on theoretically in MTT.

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\begin{array}{rl}
(\mathrm{SemR}_2, \mathrm{SemR}_1) \Leftarrow \mathcal{G}_{\mathrm{Sem.comp}} \Rightarrow \mathbf{SemR} \Leftarrow \mathcal{G}_{\mathrm{Sem.para}} \Rightarrow & \mathrm{SemR} \\
\Uparrow \mathcal{G}_{\mathrm{Sem\text{-}DSynt}} \Downarrow & \\
(\mathrm{DSyntR}_1, \mathrm{DSyntR}_2) \Leftarrow \mathcal{G}_{\mathrm{Sem.comp}} \Rightarrow \mathbf{DSyntR} \Leftarrow \mathcal{G}_{\mathrm{DSynt.para}} \Rightarrow & \mathrm{DSyntR} \\
\Uparrow \mathcal{G}_{\mathrm{DSynt\text{-}SSynt}} \Downarrow & \\
(\mathrm{SSyntR}_1, \mathrm{SSyntR}_2) \Leftarrow \mathcal{G}_{\mathrm{SSynt.comp}} \Rightarrow \mathbf{SSyntR} & \\
\Uparrow \mathcal{G}_{\mathrm{SSynt\text{-}DMorph}} \Downarrow & \\
(\mathrm{DMorphR}_1, \mathrm{DMorph}_2) \Leftarrow \mathcal{G}_{\mathrm{DMorph.comp}} \Rightarrow \mathbf{DMorphR} & \\
\Uparrow \mathcal{G}_{\mathrm{DMorph\text{-}SMorph}} \Downarrow & \\
(\mathrm{SMorphR}_1, \mathrm{SMorph}_2) \Leftarrow \mathcal{G}_{\mathrm{SMorph.comp}} \Rightarrow \mathbf{SMorphR} &
\end{array}
$$

Figure 6: Extended MTT Model

A paraphrasing grammar $\mathcal{G}_{\mathcal{S}.\mathrm{para}}$ is defined over structures of a single given stratum $\mathcal{S}_i$. Its rules identify a fragment of a well-formed structure S_s at $\mathcal{S}_i$ which can be paraphrased, replace this fragment by its paraphrase, adjusting it further if necessary, and connect the substitute with its context in S_s in order to convert it into a well-formed S_t. Note that even in such applications as text synthesis, which often serves as the prime example for transduction, a "factoring in" of paraphrasing grammars can be of great advantage — for instance to realize aggregation, i.e., fusion of structures, like conjunction reduction, in order to avoid repetition; cf., *Mary is rich and John is rich* vs. *Mary and John are rich*.

A composition grammar $\mathcal{G}_{\mathcal{S}.\mathrm{comp}}$ is defined over structures of a single given stratum $\mathcal{S}_i$. Each of its rules (a) identifies two structures $S_{s.i}$ and $S_{s.j}$ out of a given set of structures such that $S_{s.i}$ and $S_{s.j}$ fulfill the following condition: $S_{s.i}$ contains a node n with a label l_n which possesses an uninstantiated slot $r_{n\text{-}k}$ with restrictions $R_{r.n\text{-}k}$, while $S_{s.j}$ possesses a node m with a label l_m which fulfills the restrictions $R_{r.n\text{-}k}$; (b) connects n with m by an arc labeled $r_{n\text{-}k}$.

5. Conclusions

In the past, it was argued that MTT is a purely translative device. In this paper, we attempted to argue that while translation is adequate for inter-level mapping of structures, it falls short, at least from the formal point of view, of modeling paraphrasing. In other words, while translation is fine for the realization of the meaning-to-text axis it is not for the realization of the meaning-to-meaning axis. True, translation is powerful enough to serve as a fundament of paraphrasing as well, but then it leads to costly (in terms of performance time and space) implementations that lack theoretical and practical justification.

The firm denial of transformation in the MTM can be partially explained by the attempt to demarcate MTT as a dependency theory from constituent-oriented theories, which are indeed in their nature fully transformational. However, there is

no equivalence «transformation ≡ constituency», i.e., if we say «transformation», we do not need to say «constituency». As demonstrated by the LF- and semantic paraphrasing exercises, transformation is also at the heart of holistic dependency-driven models such as the MTM. We think that the time has come to come up with formal models for paraphrasing and composition that are based on transformation. While for composition, this has been done to a certain extent by S. Kahane and F. Lareau, paraphrasing still awaits its turn.

Acknowledgements

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