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# Inference and Domain Independent Mappings in Metaphor Understanding

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## Abstract

We present a computationally-oriented formal semantic framework to address the interpretation of metaphorical text. The framework builds on two main features: inference on source domain terms and a set of special mappings. Such mappings are domain-independent and are adjuncts to any conceptual metaphor.

## 1 Introduction

We assume the general view that metaphor understanding involves some notion of events, properties, relations, etc. that are transferred from a source domain into a target domain. In this view, a metaphorical utterance conveys information about the target domain. We are particularly interested in a type of metaphorical utterances that we call *map-transcending*. A characteristic of *map-transcending* metaphor is that finding a target correspondent for every aspect of the source domain is a difficult task which, in some cases, seems to be plainly impossible. Thus, this type of metaphor poses great difficulties for correspondence-based approaches (Lakoff, 1993) which require to establish a parallelism between the source and target domains to explain metaphor.

An account of metaphor interpretation ought to explain what extra information *map-transcending* entities convey and it should provide a viable (computational) mechanism to explain how this transfer of information occurs. Moreover, it should do so by taking into account the fact that metaphor is a highly contextual phenomenon.

This paper addresses these two issues: Firstly, it builds on Agerri et al. (2007) to provide a formal set of invariant mappings that we call View-Neutral Mappings Adjuncts (VNMA) for the interpretation of *map-transcending* metaphor. Secondly, it grounds the invariant mappings on a (modified) computationally-oriented formal semantic framework for the interpretation of metaphor in discourse (Kamp & Reyle, 1993; Asher & Lascarides, 2003).

We introduce in section 2. the problem of interpreting *map-transcending* metaphor. Section 3. introduces our approach to metaphor interpretation. Section 4. describes two VNMA in detail. In section 5. we extend Discourse Representation Theory (DRT) (Kamp & Reyle, 1993; Asher & Lascarides,

2003) to provide formal account of metaphor interpretation based on the two main features: Source domain reasoning and VNMA. We finish with some concluding remarks in section 6.

## 2 Missing Correspondents

We do not aim to judge when an utterance is to be considered metaphorical. Instead, our goal is to explain how a sentence such as (1) containing a map-transcending metaphor can be interpreted:

- (1) “McEnroe starved Connors to death.”

It would be natural to infer, from our knowledge about McEnroe and Connors, that (1) is used to describe a tennis match. The meaning conveyed by the metaphor ‘starving to death’ may be understood as an example of the conceptual metaphors (or, in our terminology, “metaphorical views”) DEFEAT AS DEATH and NECESSITIES AS FOOD. However, these metaphorical views would not contain any relationship that maps the specific *manner* of dying that constitutes *being starved to death*. Yet one could argue that the *manner* of Connors’s death is a crucial part of the informational contribution of (1). For cases such as this, we say that “starving to death” is a map-transcending entity as it goes beyond known mappings).

A way to address this would be to create a new view-specific mapping that goes from the form of killing involved in *starving to death* to some process in sport, but such enrichment of mappings would be needed for many other verbs or verbal phrases that refer to other *ways* in which death is brought about, each requiring a specific mapping for each metaphorical text. Thus, finding adequate mappings could become an endless and computational intensive process. Moreover, we may even find cases in which it is not possible to find a plausible mapping. Consider the following metaphorical description of the progress of a love affair:

- (2) “We are spinning our wheels.”

It is not very clear what could be a target correspondent for ‘wheels’; the unavailability of a correspondent would therefore prevent the source to target transfer of information needed for the interpretation of the metaphorical utterance. Thus, an account of metaphor ought to explain what extra information map-transcending entities provide. Furthermore, how the transfer of information occurs should be accounted for in a viable computational manner.

### 3 Source Domain Reasoning and VNMA's

ATT-Meta (Barnden & Lee, 2002) is an AI System and approach to metaphor understanding that, apart from providing functionalities such as uncertainty and conflict handling, introduces two features central to the interpretation of metaphorical texts such as (1) and (2): First, instead of attempting the creation of new mappings to extend an existing metaphorical view, ATT-Meta employs query-driven reasoning within the terms of the source domain using various sources of information including *world* and *linguistic knowledge*. The nature of source domain reasoning in metaphor interpretation has not previously been adequately investigated, although a few authors have addressed it to a limited extent (Hobbs, 1992; Martin, 1990; Narayanan, 1997). Second, previous work (Barnden et al., 2003) has shown evidence that there are metaphorical aspects (relations between events such as *causation* and event properties such as *rate* and *duration*) that, subject to being called, invariantly map from source to target whatever metaphorical view is being used. We refer to these type of mappings as VNMA's. A detail analysis of (1) illustrates the role of these two features:

(1) “McEnroe starved Connors to death.”

Assuming a commonsensical view of the world and if (1) is being used metaphorically to describe the result of a tennis match, a plausible target interpretation would be that McEnroe defeated Connors by performing some actions to deprive him of his usual playing style. In the ATT-Meta approach, source domain inferencing produces a proposition to which we may apply a mapping to transfer that information. Thus, and assuming a commonsensical view of the world, a source domain meaning would be that McEnroe *starved* Connors to death in a biological sense. The source domain reasoning can then conclude that McEnroe *caused* Connors's death by *depriving* or disabling him. Leaving some details aside, the partial logical form (in the source domain) of the metaphorical utterance (1) may be represented as follows (without taking into account temporal issues):

(i)  $\exists x, y, e (McEnroe(x) \wedge Connors(y) \wedge starve - to - death(e, x, y))$

This says that there is an event  $e$  of  $x$  starving  $y$  to death. It may be suggested that if we were trying to map the partial expression (i), its correspondent proposition in the target could be expressed by this formula:

(ii)  $\exists x, y, e (McEnroe(x) \wedge Connors(y) \wedge defeat(e, x, y))$

According to this, the event of  $x$  defeating  $y$  in the target would correspond to the event of  $x$  starving  $y$  to death in the source. However, “McEnroe starved Connors to death” suggests a connotation that “McEnroe kill/defeat Connors” lacks, namely, something related to the manner in which Connors

was defeated. Following this, *starving* may be analyzed as a causative and decomposed into the cause  $e_1$  and its effect:

$$(iii) \exists x, y, z, e_1, e_2, e_3 (McEnroe(x) \wedge Connors(y) \wedge food(z) \wedge starve(e_1, x, y) \wedge death(e_2, y) \wedge deprived(e_3, y, z) \wedge cause(e_1, e_3))$$

Note that by factoring out “starving to death” in this way we not only distinguish the cause from the effect but doing so allows us to establish a relation between “death” in the source to “defeat” in the target using the known mapping in DEFEAT AS DEATH.

Now, by means of lexical information regarding ‘starving’, it can be inferred that McEnroe deprived Connors of a necessity (see, e.g., Wordnet), namely, of the food required for his normal functioning (the NECESSITIES AS FOOD metaphorical view would provide mappings to transfer food to the type of shots that Connors *needs* to play his normal game). In other words, Connors is defeated by the particular means of depriving him of a necessity (food) which means that being deprived causes Connors’s defeat. This fits well with the interpretation of (1) where McEnroe’s playing deprived Connors of his usual game. Moreover, linguistic knowledge also provides the fact that starving someone to death is a gradual, slow process. The result of source domain inferencing may be represented as follows:

$$(iv) \exists x, y, z, e_1, e_2, e_3 (McEnroe(x) \wedge Connors(y) \wedge food(z) \wedge starve(e_1, x, y) \wedge death(e_2, y) \wedge deprived(e_3, y, z) \wedge cause(e_1, e_3) \wedge cause(e_3, e_2) \wedge rate(e_1, slow))$$

‘Slow’ refers to a commonsensical source domain concept related to the progress rate of *starving*. The existing mapping DEFEAT AS DEATH can be applied to derive, outside the source domain, that McEnroe defeated Connors, but no correspondences are available to account for the fact that McEnroe *caused* the defeat of Connors by depriving him of his normal play. Furthermore, the same problem arises when trying to map the slow progress *rate* of a process like starving.

In the ATT-Meta approach to metaphor interpretation, the mappings of *caused* and *rate* discussed above are accomplished by means of VNMAAs (the Causation and Rate VNMAAs, respectively). VNMAAs account for the mapping of aspects of the source domain that do not belong to a specific metaphorical view but that often carry an important informational contribution of the metaphorical text. These source domain aspects are captured as relationships and properties (causation, rate, etc.) between two events or entities that, subject to being called, identically transfer from source to target.

Summarizing, the ATT-Meta approach uses the following main processes for the understanding of map-transcending metaphor: 1) Construction of

source domain meaning. 2) Source-domain reasoning using the direct meaning constructed in 1) plus world and linguistic knowledge about the source domain. 3) Transfers by application of specific mappings in metaphorical views and VNMAAs.

#### 4 VNMAAs

The VNMAAs and source domain inference avoids the need to extend the mappings in the metaphorical view for each particular text we need to process, e.g., to include information about “depriving of a necessity”, “food” or “causing Connors’s death”. VNMAAs transfer those properties or relations between mapees that are *view-neutral*. VNMAAs are *parasitic* on the metaphorical views in the sense that they depend on some mappings to be established for the VNMAAs to be triggered. That is why VNMAAs are merely “adjuncts”. VNMAAs can also be seen as pragmatic principles that guide the understanding of metaphor by transferring those aspects of the source domain that remain invariant.

In example (1), there are two VNMAAs involved in the transfer of the causation and the “slowness”, namely, the Causation and Rate VNMAAs which are described below.

##### 4.1 *Causation/Ability*

There are relationships and properties (causation, (dis)enablement, etc.) between two events or entities that identically transfer from source to target. We use the  $\mapsto$  symbol to express that the mapping is a default.

**Causation/Ability VNMA:** “Causation, prevention, helping, ability, (dis)enablement and easiness/difficulty relationships or properties of events between events or other entities in the source domain, map to those relationships between their mapees (if they have any) in the target.” This VNMA could be represented as follows:

$$\textbf{Causation: } \forall e_1, e_2 (\textit{cause}(e_1, e_2)_{\textit{source}} \mapsto \textit{cause}(e_1, e_2)_{\textit{target}})$$

As an additional note, the specific mapping of each event or state variable does not depend on the VNMA but on the metaphorical view in play. For example, if we consider the contemporary situation in which McEnroe and Connors are tennis pundits on TV, we may need a metaphorical view such as ARGUMENT AS WAR to interpret the utterance “McEnroe starved Connors to death”. In other words, VNMAAs do not establish the mapees between source and target.

## 4.2 Rate

**Rate:** “Qualitative rate of progress of an event in the source domain maps identically to qualitative rate of progress of its mappee. E.g., if an event progresses slowly (in the context of the everyday commonsensical world), then its mappee progresses slowly (in the target context)”. Consider the following example:

(3) My car gulps gasoline.

Briefly, the metaphorical view involved is MACHINES AS CREATURES, that maps biological activity to mechanical activity. Source domain reasoning may be performed along the following lines: It can be inferred that gasoline helps the car to be alive, therefore, it helps the car to be biologically active. The Causation/Ability VNMA (which deals with helping) combined with the above metaphorical view provide the target domain contribution that gasoline helps the car to run. Given that we can assume that an act of gulping is normally moderately fast the use of the Rate VNMA allows us to conclude that the car’s use of gasoline is moderately fast. The formal representation is as follows:

**Rate:**  $\forall e, r (rate(e, r)_{source} \mapsto rate(e, r)_{target})$

If the rate an event  $e$  in the source is  $r$ , then the rate maps to the mappee event in the target, that is, it also has rate  $r$ ;  $r$  refers to the qualitative rate of progress or duration of an specific event  $e$ .

## 5 Metaphor in a Semantic Framework

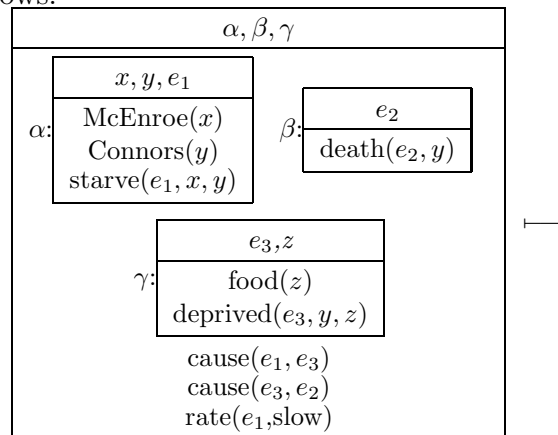
Embedding the VNMAs in a semantic framework for metaphor interpretation is useful as a first step towards their implementation in the ATT-Meta system, but it is also interesting in its own right to show the contribution of the ATT-Meta approach to the semantics of metaphor. In the somewhat simplified analysis of example (1), the important fact that the source domain reasoning performed by ATT-Meta is query-driven has not been sufficiently stressed. Although in previous sections we used various sources of contextual information to license certain source domain inferences, we have considered isolated metaphorical sentences, and metaphor understanding has been illustrated as a process of forward reasoning from the direct meaning of utterances (in the source domain), and the application of various metaphorical mappings to the conclusions of source domain reasoning to arrive at the informational contribution in the target. Furthermore, other possible inferences that could be drawn were ignored without specifying any principles or criteria whereby the reasoning could be guided towards the particular informational contributions discussed. The notion of discourse-query-directed

reasoning provides such a guidance. When analyzing previous examples, we assume that the surrounding discourse context supplies queries that guide source domain reasoning in broadly the reverse order to that in which we described them in section 3.

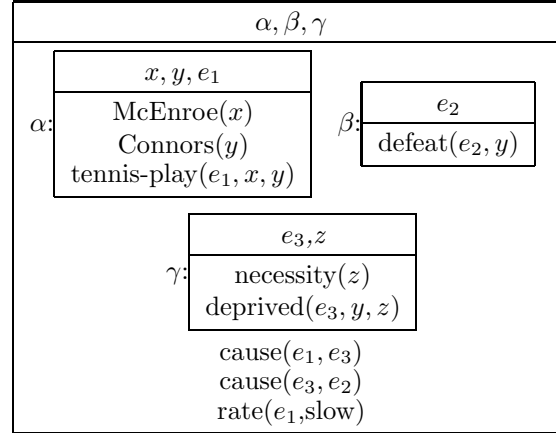
Summarizing, various sources of background knowledge were used in the interpretation of (1): a) View-specific mappings provided by the relevant metaphorical views (DEFEAT AS DEATH and NECESSITIES AS FOOD); b) Linguistic and contextual information necessary for source domain reasoning; c) Relations and properties between events such as *causation* and *rate* that are inferred in the source; d) VNMA that transfer event relations and properties from source to target. We should add that our approach is compatible with the representation of rhetorical relations to account for the discourse structure.

### 5.1 *Semantic Representation*

Metaphor is a highly contextual phenomenon, and one of the most interesting semantic approaches that model context are dynamic semantics such as Discourse Representation Theory (DRT) and its variants (Kamp & Reyle, 1993; Asher & Lascarides, 2003). We adapt their semantic representation techniques to construct deep semantic representations of metaphorical texts. We are not able to in this paper to provide a detailed description of the semantic construction procedure due to lack of space, but the general idea is that the conclusion of source domain inference and the query are both represented as DRSs. Then interpretation would amount to ATT-Meta mapping the source to the target using various view-specific mappings and VNMA. In other words, the source DRS would be the input for what the ATT-Meta system does when interpreting metaphor – it will reason with it, producing an output of inferred target facts which we may also represent by means of an DRS. The result of reasoning in the source domain to interpret (1) would look as follows:



where  $\alpha$  and  $\beta$  are labels for DRSs and  $\mapsto$  mappings (VNMA and central mappings) needed in the interpretation of the metaphorical utterance. Importantly, the VNMA would pick upon aspects such as causation and rate from the source to transfer them to the target producing an output which could also be represented as a DRS:



This formal representation integrates the systematicity of mapping invariantly certain aspects of metaphorical texts by formulating them as relations and properties of events. For this purpose we need to specify the construction rules of DRSs to include those aspects that are to be made explicit in the interpretation of metaphor. We also need to capture the interaction of the various sources of information used (linguistic knowledge, world knowledge, etc.) to infer causation and rate in the source domain DRS. We briefly outline how this works in the next section.

## 5.2 Background Knowledge

Source domain reasoning partially relies on inferences provided by the discourse context and linguistic and world knowledge. In the ATT-Meta system, world knowledge roughly corresponds to source domain knowledge. On the one hand, we have been using our commonsensical knowledge about McEnroe and Connors to interpret example (1) as metaphorically describing a tennis match. On the other hand, linguistic knowledge is used to *pretend* that the direct meaning of the metaphorical utterance is true, which allows to derive *causation* and *rate*. Thus, we assume that the understander has some world knowledge that provides information about “starving someone to death”:

- If  $e_3$  where  $y$  is deprived and  $e_1$  where  $x$  starves  $y$  are connected, then by default,  $e_1$  *causes*  $e_3$ .
- If  $e_2$  where  $y$  dies and  $e_3$  where  $y$  is deprived are connected, then by default,  $e_3$  *causes*  $e_2$ .

- If  $e_1$  where  $x$  starves  $y$ , then by default, the rate of progress of  $e_1$  is *slow*.

Furthermore, common sense about causation tells us that “if  $e_1$  causes  $e_3$  then  $e_3$  does not occur before  $e_1$ ”. Following this, the knowledge needed to interpret example (3) needs to include the that the drinking rate is fast:

If  $e$  where  $x$  gulps, then by default,  $x$  in  $e$  drinks moderately fast.

In order to include VNMA properties (and not only relations) in this framework, we assume a conceptualist point of view and consider that properties such as rate or value-judgement denote *concepts* (fast, slow, good, bad) which may correspond to the absolute rate in a commonsensical view of the world. Its representation in our semantic framework could be defined by adding an extra clause to the definition of DRS-formulae:

- If  $P$  is a property symbol and  $e$  and  $r$  are an event label and a property label respectively, then  $P(e, r)$  is an DRS-formula.

Thus, a rule encoding contextual knowledge to infer rate in the source would look as follows:  $gulps(e, x, y) \rightsquigarrow fast(e)$ . Supported by this rule we can then infer an event property in the source for its subsequent transfer to target via the Rate VNMA (when the Rate VNMA is instantiated):

**Rate:**  $(fast(e) \rightsquigarrow rate(e, fast))$

## 6 Concluding Remarks

This paper investigates the formalization and semantic representation of the ATT-Meta approach to metaphor interpretation. The ATT-Meta approach is backed up by a powerful implementation that performs sophisticated reasoning to interpret metaphorical utterances. We have focused on description and formalization of several VNMA, mappings for the systematic transference of invariant aspects from source to target. We have shown how a dynamic semantic approach can be adapted for these purposes to offer an unified semantic representation of ATT-Meta’s view of metaphor interpretation.

Map-transcending entities pose a problem for several analogy-based approaches to metaphor interpretation, both from a computational and a theoretical point of view. With respect to the computational approaches, theories of metaphor interpretation based on analogy (Falkenhainer et al, 1989; Holyoak & Thagard, 1989) usually require a conceptual similarity between the source and the target domains. Map-transcending entities need to be mapped by extending on the fly the metaphorical views with new correspondences. We have argued that this strategy is both computationally expensive and in some cases, plainly impossible.

Formal semantic approaches to metaphor (Asher & Lascarides, 2001) do not account for map-transcending metaphor entities. Other works (Hobbs, 1992; Martin, 1990; Narayanan, 1997) have addressed source domain reasoning to a limited extent, but its role in metaphor interpretation has not previously been adequately investigated. Moreover, map-transcending entities pose a problem for analogy-based approaches to metaphor interpretation (Falkenhainer et al., 1989), which usually require a conceptual similarity between the source and the target domains.

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