Modelling the Mapping Mechanism in Metaphors*

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Human thought and reasoning is replete with analogies: from the use of metaphor in everyday speech to the association of ideas that inspires a new theory. It has long been a dream of researchers in artificial intelligence to build a computer program that uses analogy, so that we may better understand how human analogical reasoning is possible, and so we can apply it to solve technological problems.
- Alan Bundy (Owen, 1990: Foreword)

This paper examines some current issues in the syntax and semantics of metaphor and analogy. Theories of metaphoric alignment, structure-mapping and an anti-unification algorithm for tracking several kinds of metaphors are explored.

Keywords: Metaphors, analogy, creativity

1. Introduction

The goals of this paper are: (1) to examine some current issues in metaphor and analogy; (2) to explore the application of structure-mapping theory (SMT) to metaphor; (3) to appraise the heuristic-driven theory projection (HDTP) and its application to different types of metaphors; and (4) to advocate a conceptual
integration of SMT and HDTP.

Metaphor as a basic cognitive mechanism underlies human reasoning. It is common knowledge that the use of metaphor is pervasive in our everyday thought patterns, linguistic repertoires, and perceptual experiences (cf. Lakoff & Johnson, 1980). It is also customary that in metaphors there is the use of a set of correspondences between two conceptual or experiential domains where one of the domains (commonly referred to as the source) assists humans to structure, understand and reason about the other domain (called the target) (cf. Ruiz de Mendoza, 2003). On the applicability of metaphor to cognitive activities, Lakoff & Johnson (1980: 5) succinctly paraphrase it thus: “The essence of metaphor is understanding and experiencing one kind of thing in terms of another.” This suggests that humans process metaphors by using a mapping or projection mechanism. With the aid of the conceptual metaphor ARGUMENT IS WAR, Lakoff & Johnson (1980) emphasise that concepts of cognition are metaphorically structured, motoric activities are metaphorically structured, and the bulk of language use is also metaphorically structured. The in terms of another component of metaphor entails a partial mapping of one experiential domain onto a different experiential domain, and understanding the semantic content of one provides clues for the other.

Metaphors are usually systematically structured as the following ARGUMENT IS WAR conceptual metaphor examples from Lakoff & Johnson (1980: 4) show:

(i) He attacked every weak point in my argument.
(ii) I demolished his argument.
(iii) I’ve never won an argument.

Arguing involves the use of words to establish superiority of claims between a defender and an opponent. As such, arguments are partially structured by the concept of war. Though no physical battle may be involved, there is a verbal battle, and the structure of an argument — attack, defence, counterattack — reflects this (cf. Lakoff & Johnson, 1980). Similarly, the TIME IS MONEY metaphoric concept reveals how time like money is valuable, can be saved, spent, wasted and invested.

Following Lakoff & Johnson (1980) and Lakoff & Turner (1989), Ruiz de
Mendoza (2003: 113) sketches the systematic structure of metaphors as follows:

- Metaphors involve two domains;
- The structure and logic of the source domain is mapped onto the structure and logic of the target domain (this means that the primary function of a metaphor is understanding);
- The relationship between the source and target of a metaphor is the “is-a” kind.

Additionally, we subscribe to the view that the following hold too:

- The mapping in metaphors is carried out across domains;
- The mapping is always uni-directional: only the source is projected onto the target domain, and the target domain is not simultaneously mapped onto the source domain (in accordance with the standard projection principle in the cognitive theory of metaphor and metonymy).

2. ANALOGICAL REASONING

Reasoning by analogy is an activity which involves projecting elements from a particular situation onto elements in another situation with the aim of preserving the relationships between the elements in each situation. The process of reasoning and learning by analogy can be informally explained with the following representative classroom scenario from Winston (1980: 690),

A teacher tells a student that the voltage across a resistor can be calculated by thinking about the water pressure across a length of pipe. The student correctly finds the voltage without knowing Ohm’s law.

The teacher instructs the student in two different voltage-resistance-current situations and tells the student to formulate a law. The student invents Ohm’s law.

The teacher suggests generalizing from the water-pipe law and Ohm’s
law. The student formulates a linear constraint that involves forces and flows.

What Winston purports here is that analogical reasoning calls for a comparison that enables one to invent a previously unknown concept, thereby resulting in generalisation. A decade later, Owen (1990: 1) affirmed this fact: ‘… knowledge of useful analogies in a domain can indicate directions for generalisation. Such generalisations can represent major breakthroughs in the understanding of a domain.’

Winston’s computational account of analogy employs the following features:

- Situations are represented using relations between pairs of parts.
- The similarity between two situations is measured by finding the best possible match according to what is important in the situations themselves.
- A constraint such as Ohm’s law is learned as a by-product of mapping the parts of a situation in a well-understood domain into the other parts of another situation in an ill-understood domain.
- Causes found in a remembered situation can supply suggestive precedents.
- Memory is searched for situations that are likely to be similar to a new, given situation.

The system is implemented with the analogical representation of knowledge, albeit only syntactically. The analogical operation, therefore, is implicit in the symbolic matching.

According to Owen (1990: 47),

An analogy match is a set of **positional associations** between symbols in the logical terms; i.e. consists of elements of the form

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((symbol₁, position₁), (symbol₂, position₂))
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where symbol₁ has position₁ (a position is represented as a sequence of successive argument positions) in term₁ and likewise for symbol₂, position₂ and term₂.
We hold the view that although the two symbols are analogues, much more than ‘positional associations’ is the ‘relational matching’ of relevant features across domains because the mapping in analogy is usually partial.

Gust, Kühnberger & Schmid (2006: 100) identify three broad types of analogies. The first is proportional analogies. They have the form \((A : B) :: (C : ?)\) which reads ‘\(A\) is to \(B\) as \(C\) is to ?’ where \(A\), \(B\) and \(C\) are given and the blank with the question mark is to be determined by making a choice from a finite set of options. For instance, in \(DOG : CAT :: CAT : MOUSE\) (cf. Owen 1990), a simple proportional analogy can be sketched based on the assumption that there is a ‘to chase’ relationship as follows:

\[
\begin{array}{c}
\text{chases (dog, cat)} \\
\text{chases (cat, mouse)}
\end{array}
\]

Proportional analogies are mostly studied in natural language, geometric figures, and in string domains.

The second class of analogies is predictive analogies. These explain a novel domain (target) by enunciating similarities with a given domain (source). Extended metaphor expressions in natural language and complex conceptualisations of physical correlations, such as the Rutherford analogy and water-pipes are good examples of this type of analogies. The third group comprises analogical problem solving which is used to solve a problem by transferring a solution from a well-known domain to an unknown domain. Developing a new computer program code from an existing program (e.g. LISP) is an instance of analogical problem solving.

From the foregoing, it can be arguably stated that analogy as a concept includes the following:

- A comparison between two domains;
- Drawing a comparison in order to show a similarity in some respect;
- Partial similarities between different situations that support further inferences; and
- A justifiable similarity-based projection between two fields of
knowledge, in order to establish empirical explanatory inferences.

3. ANALOGY vs. METAPHOR

From our explication of analogy in the previous section, it is pretty the case that analogy is different from metaphor in several respects. One, whereas analogy is a logically structured pattern of reasoning, metaphor is more noticeable in language use (although many speakers are unconscious of this fact). Two, while analogy is mostly suited for problem solving tasks, this is not the case for metaphor. Three, analogy is easier to simulate as a computational model than metaphor because of the former’s tractability. Simulating natural language metaphor is one of the greatest challenges of artificial intelligence (AI). Because of the multi-dimensional occurrence of metaphors (e.g. in poetry, everyday expressions, scientific writings etc), they are prone to ambiguities. Each writer or speaker has an intended meaning to pass across, which may not be immediately obvious or accessible by the audience. Nonetheless, the class of natural language metaphor that projects relational facts is structurally similar to analogy, and is formalizable. A knotty issue, though, is how to fully account for contextual knowledge and interlocutors’ unstated goals in communication. These call for a lot of assumptions in simulation models. Finally, analogical reasoning gives useful insights about the structuring of metaphors for cognition and creativity. Analogical relation is inherent in metaphor.

4. GENTNER’S STRUCTURE — MAPPING THEORY

The structure-mapping theory (SMT) offers a cognitive explanation of how humans carry out analogical tasks. It describes the set of implicit rules by which people interpret analogy and other similarity-related phenomena. Gentner (1983, 1988) and Gentner, Bowdle, Wolff & Boronat (2001) state that the central claim of SMT is that an analogy is a mapping of knowledge from one domain (the base or source) into another (the target), which conveys that a system of relations known to hold in the base also holds in the target. The core emphasis of SMT is a structural view of analogy based on relational projections. In other words, an analogy is a way of establishing relational
commonalities independently of the objects to which those relations apply.

Falkenhainer, Forbus & Gentner (1989: 3) argue that structure-mapping defines similarity in terms of matches between the internal structures of the descriptions being compared. Structural alignment is the main feature of analogical mapping. The alignment process is effected by (i) one-to-one correspondences, (ii) parallel connectivity and (iii) following a systematic principle. The one-to-one correspondence ensures that the comparison is one that maintains an isomorphism between elements of both domains. For parallel connectivity, the arguments of corresponding predicates should also correspond. The systematicity principle holds when a system of relations connected by higher-order constraining relations is preferred over one with a smaller system of matches. Mature adults prefer to map systems of predicates that contain higher-order relations, rather than mere isolated predicates. This indicates a preference for coherence, deductive aptness and logically sound representations in interpreting analogy. Thus, the systematicity principle does two salient things: one, it captures a tacit preference for coherence; two, it ensures a causal predictive power in analogical processing (cf. Gentner & Medina, 1998).

SMT differentiates analogy from other similarity-related phenomena. While analogy rejects object descriptions and focuses on mapping relational structures, mere-appearance matches do the exact opposite: they map object descriptions and ignore relational structures. Literal similarity combines the operations of analogy and mere-appearance matches: that is, both relational structures and object descriptions are matched. These similarity sub-types have far reaching implications on the psychological interpretation of analogical tasks.

Moreover, SMT also makes syntactic distinctions among predicate types. For instance, attributes and relations are simple predicates on the one hand, but at a higher level, first-order predicates are differentiated from second-order predicates. An attribute describes some property of an entity and thus considered as a predicate with one argument e.g. SWEET (potato). A relation is a predicate which always has more than one argument e.g. REVOLVE-AROUND (x, y). The distinction between first-order and second-order predicates can be explained with the following examples: if ROTATE (x, y) and BREAK (y, z) are first-order predicates, CAUSE [ROTATE (x, y),
BREAK \((y, z)\) is a second-order predicate. These syntactic representations are meant to be suggestive of the way people construe a situation. In essence, they are intended to accurately express what is logically possible.

Structurally, SMT characterises a number of domain-independent tacit constraints on analogical mapping. As spelt out in Falkenhainer, Forbus & Gentner (1989: 4), when \(\{B_i\}, \{T_i\}\) denote \textit{items} in the base and target representations respectively, and the subsets \(\{b_i\}, \{t_i\}\) denote \textit{objects} in the base and target representations respectively, then the following mapping \((M)\) holds:

1. Objects in the base are placed in correspondence with objects in the target:

\[
M: \quad b_i \to t_i
\]

2. Isolated object descriptions are discarded unless they are involved in a larger relational structure.

\[
\text{e.g. RED} (b_i) \quad \text{----/----} \quad \text{RED} (t_i)
\]

3. Relations between objects in the base tend to be mapped across:

\[
\text{e.g. COLLIDE} (b_i, b_j) \to \text{COLLIDE} (t_i, t_j)
\]

4. The particular relations mapped are determined by systematicity, as defined by the existence of higher-order constraining relations which can themselves be mapped:

\[
\text{e.g. CAUSE} [ \text{PUSH} (b_i, b_j), \text{COLLIDE} (b_j, b_k) \Rightarrow \text{CAUSE} [ \text{PUSH} (t_i, t_j), \text{COLLIDE} (t_j, t_k) ].
\]

These representations illustrate how structural alignment is mapped. First, \(M\) requires only \textit{one-to-one} correspondence; second, there is a corresponding parallel connectivity between the predicates of arguments mapped from one domain to the other; and third, \(M\) must be \textit{structurally consistent}: this is the underlying constraint.
5. MODELS OF METAPHORIC ALIGNMENT

Black’s (1962) proposition about the asymmetric roles of topic (i.e. target) and vehicle (i.e. source) in metaphoric processing constitutes the central claim of the modern comparison model. Building on Black’s proposition, Ortony (1979) extended Tversky’s (1977) literal similarity model to evolve his salience imbalance theory of metaphor. Ortony asserts that metaphoricity arises through salience imbalance. Thus, when high-salient features of the source align with low-salient features of the target, features associated with the vehicle are transferred to the topic. For instance, the metaphor ‘God is love’ involves an alignment of the features of the vehicle ‘love’ (e.g. being empathetic, caring, concerned for the welfare of others, sacrificing one’s comfort etc.) to the topic ‘God’. Both concepts foreground looking beyond oneself to others. Although these are abstract concepts, it is often said that God may be understood or comprehended when love is practically demonstrated.

Ortony’s model highlights the asymmetry of comparison in metaphors. The directional asymmetry results from a preference for having the salience of aligning features to be higher in the vehicle than in the topic. Whereas the shared features of both the vehicle and topic items are essential to processing metaphors, directionality appears to be a stronger consideration. Reversing the ‘God is love’ metaphor, for instance, is unacceptable by conservative Christians. When reversed to ‘Love is God,’ it contradicts the conventional hermeneutics of theological concepts. Hence, the rejection. A similar argument holds for why ‘Some surgeons are butchers’ and ‘Some butchers are surgeons’ cannot be reversed and still retain their conventional meanings (cf. Ortony, 1979).

Glucksberg & Keysar’s (1990) categorisation model is a sharp contrast to the comparison model. They regard metaphors as statements of category membership. While not discard the view that metaphors are asymmetrical, the model posits that a categorical relation is projected from the source as sets of modifiable dimensions and are simultaneously identified in the target. Glucksberg (1998: 41) explains how metaphors convey class-inclusion features. In the metaphor My lawyer is a shark, “the metaphor vehicle (shark)
is used to refer to the superordinate category of predatory creatures in general, not to smaller, concrete category of marine creatures that is also named shark.” Hence, the metaphorical attributes of shark: vicious, predatory, aggressive, and tenacious are assigned to lawyer, but the non-figurative attributes of shark: fast swimmer, having fins, sharp teeth and gills are not. We shall re-construct this metaphor later.

Proponents of SMT criticise both the comparison and categorisation models as being incapable of handling extended metaphors and being too restrictive when it comes to the core business of structural projection. As Gentner & Bowdle (1994: 352) state:

Similarity is determined not only on the basis of the intrinsic similarity of the elements comprising the base and target, but also by the extent to which these elements have corresponding roles in a common relational structure.

Interestingly, SMT has a wider scope of application, accounts for coherence imbalance as the cause of asymmetry in metaphoric mappings, and provides a basis for the inference selection process. In a slightly different way, but not essentially contradictory to the comparison and categorisation models, SMT predicts the following (Gentner, Bowdle, Wolff & Boronat, 2001: 220):

- Metaphor comprehension begins with a symmetric (non-directional) alignment process.
- If an alignment is found, then further inferences are directionally projected from source to target.
- Thus, directionality in metaphor comprehension arises after the initial state of processing.

Algorithmically, the implementation of SMT in the Structure-Mapping Engine (SME) suggests an ‘initial symmetry followed by processing asymmetry’. As elaborated in several studies (cf. Falkenhainer, Forbus & Gentner, 1986, 1989; Forbus, Gentner & Law, 1994; Gentner, Bowdle, Wolff & Boronat, 2001) SME is a computational simulation of the SMT alignment of conceptual representations. It uses graph isomorphism and structure mapping
as a computational basis for analogy and metaphor. SME adopts a local-to-global process in which object attributes and relational predicates are both used in the initial alignment process. It adheres to the systematicity of its mappings in its three-stage alignment to end up with a structural completion that can lead to spontaneous unplanned inferences (see diagram below).

The major psychological implication of SME is the way inference occurs as a spontaneous outcome of comparison; and this sometimes amazes the reasoner. A similar graph-matching model is the analogical constraint mapping engine (ACME) of Holyoak & Thagard (1989). It also employs a tree-structure representation, mapping systematicity and structural isomorphism.

In the end, a symmetric-to-asymmetric alignment process appears suitable for relational projections. The foregoing has stressed the importance of asymmetry on the one hand, and for the pivotal role of systematicity and structural alignment in a relational-based account of projection in analogy and metaphor.

6. THE SEMANTICS OF METAPHORICAL MAPPINGS

Gust, Kühnberger & Schmid’s (2006) HDTP is a formal and mathematically
sound account of metaphoric mappings. HDTP, like SMT, generates structural descriptions. However, it is primarily “a generalisation of the theory of anti-unification (AU) or the computation of the most specific generalisation”. That HDTP is heuristic-driven means finding the most specific generalisation is algorithmically constrained. Adapting Gentner’s (1983) structure-mapping for the Rutherford analogy shown in Figure 2 below, a second-order relation is defined as follows:

\[
\text{cause (attracts (sun, planet-i), revolves\_around (planet-i, sun))}
\]

However, Güst, Kühnberger & Schmid (2006) fault the SMT analysis of the metaphoric analogy ‘Electrons are the planets of the atom’ and point out some fundamental shortcomings.

- First, the mapping process in SMT is not as tangible as expected because the causal explanation is built into the modelling. Simply put, \text{revolves\_around (planet-i, sun)} and \text{revolves\_around (electron-i, nucleus)} are explicitly stated. Hence, no genuine inference is required on the part of the reader or hearer; thereby depriving analogies and metaphors of their inherent creative potentials.
- Second, the explanation is \text{physically wrong}. The \text{attracts} relations in SMT are predicated to things that are not identical. In clear terms, they correspond to different forces viz. \text{gravity} and \text{Coulomb} respectively.
- Third, it is doubtful whether Figure 2 above is a natural description of how analogies are used in physics as suggested in the described case.
Whereas it is possible to quantify on the atom side that the nucleus is heavier than the electron, it is not the case that the electron revolves around the nucleus. This is where the inference from the data becomes crucial.

Fourth, specifying the semantics of the described representation would be very problematic — if not entirely impossible — because a match of relations that are similarly labelled is merely a match of syntactic strings that does not involve any kind of semantics.

Their main objection to SMT is its intrinsic lack of productivity. To remedy this defect, the domains are modelled via conceptual predictive projections, without distorting the asymmetry. A set of axioms $A_S$ which induce a theory $Th_S$ is used to model the solar system quantitatively as expressed in the Figure 3 above.

**Fig. 3.** Modeling the physics of a solar system using a theory $Th_S$ (cf. Gust, Kühnberger & Schmid, 2006)
When planet and sun are regarded as objects, it would be possible to experimentally measure the mass of an object, the distance between two objects, and a force between two objects, namely gravity as well as the centrifugal force between two objects.

Similarly, a set of axioms $A_T$ which induce a theory $Th_T$ about atoms is used to conceptualise the atom model in Figure 4.

The purpose of the modelling is to induce analogy such that a conceptualisation of the solar system can be used to derive a novel conceptualisation of the Rutherford atom model. This is why the conceptualisation of the atom is not as informative as that of the solar system. Otherwise, inducing analogy would be unnecessary. The projections in HDTP serve as the basis for abstracting the generalisations of the two theories — $Th_S$ and $Th_T$. Gust, Kühnberger & Schmid (2006: 108) explain the motive:

The underlying idea is to compute possible generalizations stage-by-stage together with their substitutions governed by a certain heuristics. The restriction to the described subclass of second-order generalizations ensures finiteness of this approach. After the generalization as many source facts and laws as possible are transferred to the target provided the transfer does not result in an inconsistency. The process of the generalization and the transfer of facts and laws we call *theory*...
projection. The motivation to transfer as many axioms as possible to the target domain is related to the systematicity principle of the SME model.

Gentner, in her comments on our draft, challenges Gust, Kühnberger & Schmid’s (2006) review of Gentner’s supposed analysis of the Rutherford analogy. Her comments follow.

- First, the metaphor or analogy Gentner analysed is “The atom is like the solar system” — intended to approximate Rutherfold’s analogy of 1904—1906. It is, therefore, incorrect to state that no genuine inference is made. A learner who knows the ‘revolve’ relations in both cases was modelled. While it is correct that the ‘revolve’ relation is not inferred (but merely matched), there is actually a new inference, namely the causal relation.

- Secondly, it is stated that the explanation is physically wrong, because the attracts relation applies to two different forces: gravity and electromagnetic force. On the contrary, a crucial aspect of human analogizing (which SMT aims to capture) is the re-representation of relations at higher levels of abstraction, which allows matching between relations that are partly, but not totally, identical. Although the two forces are indeed different, both are inverse-square forces that (in Rutherford’s analogy) act to create a central force system.

- Thirdly, modern physics does not claim that the electron revolves around the nucleus. It is very clearly stated that this is a model of Rutherford’s 1904 proposal. Historically, this model paved the way for more modern models; it was partly the failure of analogical inferences derived from Rutherford’s central force model that led to the new proposal (by Bohr) of a shell model.

We shall now have a closer look at the semantics formalized in HDTP. Semantically, the analogical relation (R) in HDTP is defined as follows (Gust, Kühnberger & Schmid, 2006: 111):

Assume two theories $Th^A_h$ and $Th^A_S$ together with corresponding models $M_S$ for $Th^A_h$ and $M_T$ for $Th^A_S$ and a co-product (disjoint union)
operation \( \oplus \) are given, the analogical relation is

\[ R \subseteq \left( \text{Th}^A_{S^h} \times \text{Th}^A_{T^h} \right) \oplus \left( \text{Term} \left( \Sigma_{S^T}, V_{S^T}, C_{S^T} \right) \times \text{Term} \left( \Sigma_{T^T}, V_{T^T}, C_{T^T} \right) \right) \]

of theories is a set of pairs \(<x, y>\) such that it holds:

(i) If \(<\phi, \psi>\) is a pair of formulas and \(<\phi, \psi> \in R\), then there exists \(g \in \text{Th}^A_{G^h}\) such that \((g, \{\Theta_1, \Theta_2\})\) is an anti-instance of \(\phi\) and \(\psi\) and

\[ \text{Th}^A_{T^h} \cup E_{T} \models g\Theta_2 \leftrightarrow \psi \quad \text{and} \quad \text{Th}^A_{S^h} \cup E_{S} \models g\Theta_1 \leftrightarrow \phi. \]

(ii) If \(<t, t'>\) is a pair of \(<t, t'> \in R\), then there exists \(g \in \text{Term}_G\) such that \((g, \{\Theta_1, \Theta_2\})\) is an anti-instance of \(t\) and \(t'\) and

\[ E_{T} \models g\Theta_2 = t' \quad \psi \quad \text{and} \quad E_{S} \models g\Theta_1 = t. \]

(iii) There exists a model \(M_S\) such that \(M_S \models \text{Th}^A_{S^h}\) if and only if there exists a model \(M_T\) such that \(M_T \models \text{Th}^A_{T^h}\).

Establishing an analogical relation between the source and target domains which corresponds to an experimentally-preferred psychological interpretation of a metaphor provides the needed clues for the semantics of the metaphor. The analogical relation is derived by combining the syntactic structure of the metaphor with the relatively weak assumptions about the lexical meaning of its composite concepts to arrive at a convincing generalisation. “The lexical meaning of a concept most often does not involve a spelled-out conceptualization comparable to current scientific theories. Rather, one or more preferred properties are often associated with metaphors governing the new non-conventional meaning of the involved target concepts” (Gust, Kühnberger & Schmid, 2006: 114).

For the sake of precision, they construct the analogical relation of the metaphor ‘Electrons are the planets of the atom’ by specifying the concept \textit{planet} by its relation to \textit{sun} (which is not explicitly mentioned, but presumed to be available). In the same vein, the concept \textit{atom} indirectly introduces \textit{nucleus}. Against this background, they contend that the following specifications should
The concept \textit{sun} is a lexicalized entity. It may occur with other objects (such as planets) and build the centre of a more complex system that includes \textit{sun} and the other objects. The salient point here is that this system is finite.

The lexical meaning of \textit{planet} includes a particular relation to another object \textit{sun}, i.e. the concept \textit{planet} is partially defined via a two-ary relation \textit{revolves\_around} \((x, y)\) together with a certain sort restriction with respect to \(x\) and \(y\). The assumption \textit{revolves\_around} \((\textit{planet}, \textit{sun})\) in the source domain is the result of an anticipated inference mechanism coupled with contextual information.

The conceptualisation of \textit{planet} this way introduces a concept \textit{sun} and links both concepts to each other.

The relation \textit{revolves\_around} is the preferred property assigned to \textit{planet}.

A second-order deductive process yields a relation defined by the central body system constituted by \textit{solar system} and \textit{sun} and a \textit{revolves\_around} \((x, y)\) relation. Figure 5 below is a model which HDTP uses to abstract the generalisation that in turn establishes the fact \textit{revolves\_around} \((\textit{electron},

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\textbf{Fig. 5.} Modeling of the Source and Target Domain (cf. Gust, Kühnberger & Schmid, 2006)
nucleus) in the target domain.

HDTP, therefore, is a formal specification that induces inferences in analogies and metaphors. Our general impression is that HDTP supplies an essential feature which SMT lacks: a formalisation of the semantics of metaphoric mapping. The carefully spelt-out algebraic syntax and semantics of HDTP as well as its anti-unification algorithm enable it to produce plausible results when applied to predictive analogies in qualitative physics, to relational properties in metaphors, to analogies involving metaphoric noun phrase modification, and to poetic metaphors (e.g. *Fog* by Carl Sandburg). While we accept this improvement over SMT, we contend that HDTP has provided an empirical formal re-validation of SMT’s psychological assumptions. Whereas the inference mechanism is implicit in SMT, HDTP’s is explicit and more logically appealing. Thus, the syntax and semantics of HDTP make it a more dynamic computational theory of characterising and implementing metaphoric analogies. But as a general remark, most of the representations used to model analogy in SME are intended to capture speakers’ natural language representations, often based on linguistic semantics or on AI knowledge representations. SMT’s major theoretical contribution to similarity-based studies is its clear demarcation between analogies and other types of similarity comparisons; its algorithm is easily adaptable.

7. METAPHORIC MAPPING AND CREATIVITY

Going by the words of Leary (1990: 2) that ‘all knowledge is ultimately rooted in metaphorical (or analogical) modes of perception thought,’ it becomes necessary to investigate how the mapping mechanism in metaphors either aids or distorts the understanding of novel expressions. In the following variants of the IDEAS ARE FOOD conceptual metaphor,

(iv) His remarks left a bad taste in my mouth
(v) I can’t digest all these ideas at once
(vi) Now there’s an idea you can sink your teeth into
(vii) He expected us to swallow his claims about the new product
(viii) Well, now, there’s food for thought
the relational components of the source domain is projected to the target domain in a way that the inference is based on the analogical projection that since people eat food to satisfy their hunger, taking in good ideas can satisfy one’s quest for knowledge.

However, there are conflicting reports as to how mapping induces understanding. While Lakoff and his colleagues assert that ‘metaphorical mappings preserve the cognitive topology (that is, the image-schema structure) of the source domain, in a way consistent with the inherent structure of the target domain,’ Murphy (1996) argues that metaphors do not in any way structure the target domain via the source, but rather the structuring of metaphors reflect structural parallelism between two domains. The asymmetry of metaphors is an empirically-substantiated fact: novel metaphors are, therefore, mostly comprehended by projecting the knowledge of the concrete source domain term to the target domain, using structural alignment.

Lakoff & Turner (1989) argue that there are three basic mechanisms for interpreting linguistic expressions as novel metaphors namely: extensions of conventional metaphors, generic-level metaphors and image-metaphors. Although it may not be very easy to mark the boundaries among these models when humans process novel metaphors, we suggest that any interpretation whatsoever must be rooted in the context of the speaker / hearer interaction, the cultural experience as well as world view of the interlocutors. So, the import of conventional meaning cannot be relegated to the background. The comprehension process involves a combination of the conceptual framework, lexical distribution and pragmatic value of the metaphors.

Since novel metaphors may be interpreted differently by different individuals based on their familiarity with the conventional notions of the concepts involved, multiple interpretations are permitted (provided the asymmetry is retained). Gentner, Bowdle, Wolff & Boronat (2001) lend support to Gibbs (1996) on the assertion that many abstract domains can be construed in several different ways, and therefore can accept metaphors from multiple source domains. In addition, they add that the same source domain can provide different structures for different targets as depicted by KNOWLEDGE IS FIRE (one may pass the flame to others); LOVE IS FIRE (its heat may consume the lover); and ENVY IS FIRE (it burns upward towards its object, covering it with smoke). Therefore, the source domain term
‘fire’ is represented with multiple schemas, each being determined by alignment with the target domain. Thus, the mapping in novel metaphors may give rise to partial understanding, full understanding or outright misunderstanding, depending on the complexity of the concepts and the interlocutors’ familiarity with their conventional meanings. The pragmatics of language use also suggests that novel metaphors tend to derive their initial associations and mappings from conventional forms. All these affirm the systematicity of metaphoric processing just like analogical reasoning.

8. OUR PROPOSAL: A CONCEPTUAL INTEGRATION OF SMT AND HDTP

The class of natural language metaphors we wish to decompose are those that project relational information. These are the ones that are structurally similar to analogies. For our methodology to be effective, we build on the assertion that “what is needed for an appropriate modeling is a list of designated properties of the involved concepts” (Gust, Kühnberger & Schmid 2006: 116). In our approach, the properties comprise entities (objects) and relations (facts). Analogy is induced in the target by aligning similarly denoted relations. The alignment is not just a case of string matching (which is largely syntactic / structural). Rather, a corresponding semantic relation to

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\[
R: \text{nurture} (\text{mother, family}) \leftrightarrow \text{support} (\text{pillar, building})
\]
the preferred candidate in the source is brought to bear on the target also. The second stage results in a productive novel relational structure. We illustrate these below.

Applying HDTP to the metaphor *The pillars of society are mothers*, we suggest a conceptual abstraction of the kind: FULCRUM IS A WOMAN. We slightly modify the analogical processes in HDTP. Analysing the meaning as well as projecting a generalisation arising from the axioms of the source and target domains will lead to two stages of the analogical relation (R) in Tables 1 and 2 respectively.

Specifying the analogical relation presupposes a lot of semantic and contextual information. First, the lexical meaning of *mother* requires that one assume the collocate objects *child* and *family* in the source input $A_S$. The same applies to objects in the target domain, which serve as the input $A_T$: *pillar* and *building*. We infer two-ary relations in the source e.g. $\text{gives\_birth}(x, y)$; $\text{raised\_in}(y, z)$; $\text{nurtures}(x, z)$. Thirdly, we select $\text{nurtures}(\text{mother}, \text{family})$ as the preferred relation in the source which corresponds to $\_\_?(\text{pillar}, \text{building})$ in the target. However, we need to supply the missing predicate information in the target. Following the systematicity principle of SMT, we arrive at a semantically compatible analogical relation for the target: $\text{supports}(\text{pillar}, \text{building})$ as shown in Table 1.

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<td>$\text{gives_birth}(\text{mother}, \text{child})$</td>
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$\text{R: nurtures}(\text{mother}, \text{family}) \land \text{supports}(\text{pillar}, \text{building}) \Rightarrow \text{foundation\_of}(\text{family}, \text{society})$
The stage 2 process is where we highlight how a systematic mapping of two domains can evolve a truly analogical creativity in metaphors. To the best of our knowledge, decomposing metaphors this way is what shows the analogical tendency in metaphors. The semantics of the underlying ‘to support’ relation yields different pragmatic values for the source, target and novel domains. The systematicity principle is obeyed and the analogical transfer is productive in the novel generalisation. This results in a plausible conclusion: IF mothers nurture the family as pillars support buildings, THEN the family is the foundation of every society.

Additionally, an anonymous reviewer drew our attention to the fact that a semantically-inclined interpretation of the metaphor The lawyer is a shark will yield an analysis of the sort: the lawyer ‘deprives’ a client of money as if a greedy shark ‘deprives’ fish of its flesh. The act of “depriving” has different semantic associations for the two agents. The lawyer’s “depriving” means ‘robbing’ someone of their money while the shark’s “depriving” means ‘eating’ flesh. So, the basis of the metaphor’s meaning is on the similarity between meaning structures of “robbing” and “eating”. Hence, the need for semantic considerations in metaphoric processing, especially the semantic formalism of HDTP.

Broadly stated, our position is that an integration of structure-mapping and theory projection is what holds a promising future for making explicit the inherent analogies in natural language metaphors and the potentials for metaphors to be creative.

9. CONCLUSION

Lakoff & Johnson’s (1980) conceptual metaphor is one of the most widely studied linguistic analyses of conventional metaphors that has inspired a lot of experimental studies in cognitive science. SMT is at the core of many syntactic representations of relational facts in knowledge-based computational simulation models; its basic psychological assumptions have been validated and re-validated via several experimental investigations. HDTP is a contemporary anti-unification algorithm (with a rich formalized semantics for metaphoric relations); it has produced plausible results when applied to predictive analogies in qualitative physics, to relational properties in
metaphors, to analogies involving metaphoric noun phrase modification, and to poetic metaphors. We agree that “what is needed for an appropriate modeling is a list of designated properties of the involved concepts” (Gust, Kühnberger & Schmid, 2006:116) and advocate a two-stage analogical projection for enhancing creativity in metaphors. While not proposing an outrightly new theory of metaphoric analysis, we believe that an integration of structure-mapping and theory projection is what holds a promising future for making explicit the inherent analogies in natural language metaphors, and for tracking and implementing the complexities of natural language metaphors.

References


