Metaphor as change of representation: an artificial intelligence perspective

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1. Introduction: similarity-based metaphors versus similarity-creating metaphors

It has been noted for quite some time now that metaphors are not mere figures of speech that are only useful in poetry and prose; but, on the contrary, they form our primary mode of cognition: some would even say that they form our only mode of cognition. Metaphors have been recognized to play a crucial role in various cognitive activities such as learning and education (Petrie 1979, Sticht 1979); science (Emmet 1945, Chapter IV, pp. 68–95, Hesse 1974, 1980, Kuhn 1979, Gerhart and Russell 1984); religion (Gerhart and Russell 1984, Soskice 1985); society and culture (Schön 1979, Reddy 1979, Kempton 1987, Lakoff and Kövecses 1987, Quinn 1987); everyday language (Embler 1966, pp. 27–44, Lakoff and Johnson 1980). Moreover, it has been observed that children start using metaphorical language at a very early age (Winner 1979), and it has been argued that metaphors lend themselves to a child’s cognition in more or less the same way as they do to an adult’s cognition (Winner 1988, Chapter 6).

Given the paramountcy of the role played by metaphor in cognition, it is perhaps not surprising to find that in the past few years, metaphors have been the subject of a vigorous inter-disciplinary research—at both the empirical front as well as the theoretical one. Whereas the empirical research efforts have been concerned with observing and articulating characteristics of metaphors, and relating these characteristics to the role played by metaphor in cognition, the theoretical research has been struggling to provide a formal framework in which all the known characteristics of metaphors can be explained. Although understandably—for, in spite of some significant advances, there is still much we do not know about the cognitive processes underlying metaphors—key differences exist among scholars as to how metaphors work, or even what a metaphor is, almost everyone agrees that a metaphor involves a source (also referred to as a ‘secondary domain’ or a ‘vehicle’), a target (also known as a ‘primary domain’ or a ‘topic’), and some kind of transfer from the source to the target. Exactly what is transferred, and how it is transferred, are some of the issues on which there are varied opinions.

Yet, a view of this transference held by many, if not most, scholars of metaphor is
that it is based on some similarity between the source and the target.\textsuperscript{3} The origin of this view can be traced back to what is familiarly known as the comparison theory of metaphor (Henle 1958). Although the comparison theory of metaphor has been severely criticized at times,\textsuperscript{4} it has persevered over the years and many existing approaches to metaphor remain comparison theoretic at heart. I must emphasize that what I am calling `similarity' here includes `analogy\textsuperscript{5} as well as `structure-preserving mapping'. Again, of course, there are significant variations in how metaphor is based on similarity. For instance, Gentner (1983) argued that metaphors typically involve similarity with respect to `relations'—and higher-order relations at that—rather than `attributes.' In Indurkhya (1986), I argued that metaphor involves similarity with respect to `structure,' expressed in the form of first-order-logic axioms. However, in this paper I am not concerned with the question: `Similarity with respect to what underlies a metaphor?' But, rather, with the thesis: `Similarity in some respect underlies a metaphor'. It is this latter thesis that is taken for granted by many researchers of metaphor.

This is especially true of the few AI models of metaphor that have been proposed or implemented so far. For the most part, the term `metaphor' is used to refer to its linguistic manifestation in AI; and, consequently, the problem of modelling metaphors is addressed within the framework of Natural Language Processing. In doing so, however, it is assumed that to comprehend a metaphor is to compute the underlying similarity. For instance, Fass (1989), building up on the `preference semantics' framework of Wilks (Wilks 1975, 1978, Fass and Wilks 1983), implemented a system where literal and non-literal usage is distinguished from the violation of selection restriction rules. Once a non-literal usage is detected, the system tries to see if it is an instance of metonymy, metaphor, or ill-formedness. The basis of metaphor identification is an underlying relevant analogy between the word senses. Others have made similar presumptions (Russell 1976, Hobbs 1979, Carbonell 1982, Weiner 1984, 1985, Indurkhya 1987, Martin 1988); the main point of divergence being the techniques and the heuristics used to contain the search space. The solutions to the search problem vary from taking the similarity as explicitly given (Carbonell 1982, Martin 1988), to using salience and prototypicality to constrain what features of the source are transferred to the target (Weiner 1984, 1985). The few AI researchers who sought to model metaphor in a cognitive framework (Gentner and Stuart 1983, Gentner et al. 1987, Falkenhainer 1988), as opposed to a linguistic one, also saw the problem primarily as that of figuring out the underlying mapping.

There is perhaps a good reason for presuming the similarity thesis. There are many metaphors, especially `conventional' metaphors, to use the more clarifying terminology of Lakoff (1986), that are based on some underlying similarity between the source and the target. Yet, there are many other metaphors that are not based on any underlying similarity but, rather, they create the similarity. This characteristic of metaphors has been pointed out in the literature often (Richards 1936, Black 1955, 1977, Schön 1979, Lakoff and Johnson 1980, Chapter 22), but not yet fully incorporated in a computational framework.

At this point it may be worthwhile to emphasize the difference between similarity-based metaphors and similarity-creating metaphors. Similarity-based metaphors, corresponding to the comparison theory of metaphor, are grounded on some pre-existing similarity between the source and the target. The similarity may be explicitly stated in the metaphor, as in `the river is windy like a snake', or left implicit, as in `the river is a snake'. In a similarity-creating metaphor, on the other hand, there is no pre-
existing similarity between the source and the target. In fact, the source and the target appear to be two distinct objects completely unlike each other. The similarities are created by the metaphor. That is, after the metaphor has been assimilated, if it is assimilated at all, then there are similarities between the source and the target. For instance, suppose one is asked to compare fog with a cat. The two objects appear quite unlike each other. To appreciate the full force of similarity-creating metaphor that I am about to present, I would strongly suggest that the reader try to enumerate all possible similarities between these two objects she or he can think of before reading any further. Now consider the following verse by Carl Sandburg:

The fog comes
on little cat feet.
It sits looking
over harbor and city
on silent haunches
and then moves on.  

Now the fog at once appears as similar to the cat! Moreover, I am sure that for most people, unless they peeked ahead, the similarity between the fog and the cat that seemed obvious after reading the verse would not be included in their earlier comparison. I would argue that the similarities between the fog and the cat are created by the metaphor by providing a novel way of thinking about, or conceptualizing, the fog. If still not convinced, the reader may be able to appreciate this point better in the next section when we discuss, with some more examples, the role of similarity-creating metaphors in cognition.

I must note here that there have been some theories and models of metaphor that partially account for similarity-creating metaphors. In Indurkhya (1986), for example, there is an operator ‘Positing Structure’ that induces structure in the target domain based on the structure of the source domain. Of course, the induced structure is subject to an experimental verification in the target domain. However, any induced structure must necessarily be similar to the structure of the source domain. Moreover, since this similarity is between the source domain and the new structure of the target domain, it is a created similarity. A similar account is offered in Kittay (1987), where this process of adding structure to the target is referred to as ‘articulating the content domain by the source lexical field.’ A computational model of a similar process, under the rubric of ‘verification based learning,’ is presented by Falkenhainer (1988).

This mechanism of importing structure, which elsewhere I have referred to as ‘suggestive metaphor’ (Indurkhya 1991a, 1992), however, always adds structure to the target monotonically. That is, the existing structure of the target is not invalidated in the process. Truly creative metaphors, on the contrary, almost always work by creating a new structure in the target, a structure that is often incompatible with the existing structure of the target. This is where the theories of Indurkhya (1986), and others mentioned above, fall short. They do not provide any mechanism for changing the ontology and the structure of the target.

Being fully aware of this limitation of my earlier theory, I offered the following explanation at that time:

The explanation we offer for this phenomenon is as follows. In general, in comprehending a metaphor, there is three-way tension going on rather than two-way tension as we assumed in our theory. The interaction taking place in understanding a metaphor is not merely between the source domain and the target domain but among the source domain, the target domain and the
object or the concept that is represented in the target domain. Thus in interpreting the metaphor ‘the ship plowed through the sea’ the domains plowing and sailing interact with each other and with the actual process of sailing to produce an interpretation of the metaphor. The reason for this distinction is that our representation of an object or a concept reflects a certain perspective and in that sense is an approximation to the real nature of that object or concept. A metaphor can, by mere juxtaposition or other techniques, force us to look beyond our representation of the object in order to make sense of the metaphor. This process can give rise to a new perspective on the object that was missing from our representation. [Indurkhya 1986, pp. 546–547].

Of course, this was only an intuitive account and was not formally incorporated in the theory. In my later work, however (Indurkhya 1992), I have formalized this insight into an algebraic framework. This paper presents a computational perspective on that framework.

One may well argue that similarity-creating metaphors pose a harder problem than similarity-based ones, and, therefore, we should defer addressing them until after we have a better grasp on similarity-based metaphors. However, I would like to suggest in this paper that a different process underlies similarity-creating metaphors than the one that is responsible for similarity-based ones. Moreover, the process underlying similarity-creating metaphors can, in fact, be properly addressed from the existing AI technology. In doing so, I hope to arouse the interest of other AI researchers to investigate the nature of similarity-creating metaphors, which have been known to play a key role in many aspects of cognition.

This paper is organized as follows. In the next section I will present a brief account of the role of similarity-creating metaphor in cognition so as to provide a motivation for studying them computationally. This section will also introduce some characteristics of similarity-creating metaphors by using a few examples. In Section 3, I will present an account of similarity-creating metaphors by arguing that the underlying process is essentially that of ‘conceptualization’. In the following section, I will discuss implications of this view of similarity-creating metaphors from an AI perspective, and outline how this process might be modelled with the existing AI technology. Finally, in Section 5, I will summarize the main points of this paper.

2. Similarity-creating metaphors and cognition

In Displacements of Concepts, Schön (1963) recounts the story of a product development team that was charged with the task of improving the performance of synthetic fibre paintbrushes, which left the painted surface gloppy and discontinuous, as opposed to the smooth and continuous finish of natural fibre paintbrushes. Initially, their understanding of the painting process, and the role of paintbrush in it, was based on seeing it as a smearing process; whereby the paint sticks to the fibres when the brush is dipped in it, and when the brush is moved back and forth on the surface, some of this paint sticks to the surface. From this perspective, when the product development team compared the performances of the natural fibre brush and the synthetic fibre brush, they could find no differences. Yet the overall result, in terms of the appearance of the painted surface, was different.

The breakthrough came when some member of the team had a flash of insight suggesting that the painting process be viewed as pumping. In doing so, the concept of painting, as well as the role of a paintbrush in it, was completely transformed. Now the paint is sucked up in the space between the fibres by capillary action as the brush is dipped in the can of paint, and, when the brush is moved back and forth on the surface, the increased pressure pumps out the paint through the space between the fibres,
generating a thin spray at the place where the fibres bend away from the surface. When
the performances of the natural fibre paintbrush and the synthetic fibre paintbrush
were compared from this perspective, it was found that natural fibres formed a smooth
curve against the surface when the brush was moved back and forth on it, while the
synthetic fibres bent at a sharp angle. This observation led to a number of innovations
on the fabrication of synthetic fibres, some of which resulted in bristles that curved
smoothly; and the resulting brush did, indeed, produce a smooth painted surface.

There are a few important points that must be noted in this example. First of all, the
two different ways of viewing the painting process, structure it in radically different
ways. Even the causal structure that determines why the paint sticks to the brush after
it is dipped in the can, and why it is coated on the surface when the brush is moved back
and forth across it, is different in each case. Moreover, the primitives in terms of which
the structures are seen—or the ‘ontologies’ of painting—are different in each case.

There are two other crucial points. The flash of insight leading to the view of
painting as pumping was not triggered by some existing similarities between the
painting process and the pumping process. In fact, this is why the identification was
shocking at first—a characteristic that accompanies all creative but insightful
metaphors. Secondly, the similarities between painting and pumping were a result
of the process. That is, after a different ontology and structure of painting was created,
then there were similarities between painting and pumping. Schön was most vehement
about both these points.

The underlying process was called ‘generative metaphor’ by Schön (1979), as it
concerns generating a perspective on the target. It is this generated perspective that
determines what aspects of the target are seen as problematic, and how these problems
might be addressed. It is also from this new perspective that the target is seen as similar
to the source.

Another example of generative metaphors that Schön (1979) presented had to do
with the problem of slums in urban societies. He reviewed two ‘stories,’ which were
points of view of social-workers that exercised a considerable influence over the public
consciousness, and consequently on the social policy including legislation and
allocations of funds, at the time they were voiced. One of these stories, which was
influential in the US in the 1950s, viewed slums as ‘blighted areas’ and ‘congenital
disease’, and suggested ‘urban renewal’ as a remedy. The other one, which shaped the
public policies in the 1960s, saw slums as ‘natural communities’ and highlighted the
negative aspects of ‘urban renewal’ resulting from relocating people. Each story had
its metaphor that conceptualized the situation differently. And each conceptualization
saw the ‘problem’ differently, and sought different means of ‘solution.’

Using these examples, Schön argued that our view of social reality is constructed
through metaphors, and each of the metaphors mentioned above created the
similarities between its source and its target, rather than finding some pre-existing
ones. Lest this point is not appreciated fully—for the examples of Schön are anything
but ‘clean’—let me present it in the context of another example. Consider the source
to be a figure consisting of a hexagon and six identical circles outside it with a circle
touching each side of the hexagon at its midpoint (Figure 1(a)); and the target to be
a figure consisting of two identical equilateral triangles, one of which is flipped across
the horizontal axis passing through its centre and placed on top of the other (Figure
1(b)). Now there are no pre-existing similarities between the two figures as long as the
similarities are sought with respect to the given descriptions of the source and the
target. Yet, when the source and the target figures (Figures 1(c) and 1(d)) are
juxtaposed, the target is seen as similar to the source. The similarities are created by the metaphor, which forces one to redescribe the target—as a hexagon with six equilateral triangles outside it, with a triangle on each side of the hexagon (Figure 1(e))—so as to be similar to the source.

This example already foreshadows the account of similarity-creating metaphors that I will be proposing in the next section, namely that the creation of similarity results from a change of representation of the target. While this thesis is implicit in Black’s well-known *interaction theory,* the roots of which can be traced back to I. A. Richards’ *Philosophy of Rhetoric,* it is not explicitly brought out or elaborated sufficiently. Coupled with the vagueness with which Black articulated the interaction

![Diagram](image)

(a) The description of a geometric figure

(b) Description of another geometric figure.

(c) The figure whose description is given in (a).

(d) The figure whose description is given in (b).

(e) Redescription of Figure (d).

Figure 1. An example of how metaphors can create similarities. There are no similarities between (c) and (d) as long as the similarities are sought with respect to their existing descriptions in (a) and (b) respectively. The similarities are apparent at once, however, when the description of (d) is changed to the one shown in (e). (See also the text for further explanation.)
theory, this has led some scholars to miss this point altogether, and see the interaction theory as nothing but a variant of the comparison theory.  

Besides Schön, other scholars have recognized the importance of the role played by similarity-creating metaphors in various aspects of cognition. Gordon (1961) emphasized the role of metaphors in generating new perspectives as an aid to creative problem solving. He referred to the process as ‘making the familiar strange’ (pp. 35–36), whereby a familiar, but problematic, situation is viewed as another (something that would normally be not connected with the situation; hence the term ‘strange’) so as to get a different conceptualization of it—one that may address the problem that cannot be addressed from the familiar perspective. Interestingly, when using this heuristic to solve some problem about the target, one tries to find a source that is completely dissimilar to the target, and then force the similarity between the source and the target.

Koestler (1964, pp. 199–207) argued, citing several examples, that the hallmark of creativity, whether it be a scientific discovery or art and poetry, is not in noticing the existing similarities, but in creating newer ones: “‘Similarity’ is not a thing offered on a plate (or hidden in a cupboard); it is a relation established in the mind by a process of selective emphasis on those features which overlap in a certain respect—along one dimensional gradient—and ignoring other features... [T]he real achievement in discoveries... is ‘seeing an analogy where no one saw one before.’” (pp. 200–201).

In various kinds of learning situations also, it has been argued that it is similarity-creating metaphors that generate new information from the environment, and make new knowledge possible. For instance, Petrie (1979) has argued that metaphors are essential for bridging the gap between the old and new knowledge, and although he himself does not make a distinction between similarity-based metaphors and similarity-creating metaphors, the way he is using the term metaphor, and the characteristics he ascribes to it, leave no doubt that he is referring to similarity-creating ones. Sticht (1979) has made a similar point and strengthened Petrie’s thesis. A more recent account of similarity-creating metaphors—though they are referred to as interpretive analogy—in learning can be found in Indurkhya (1991b).

In the history and philosophy of science, Hesse and Kuhn have repeatedly pointed out that similarity-creating metaphors are an indispensable aid to scientific progress. For instance, Kuhn has noted how the characteristic of metaphors to create radically different perspectives is invaluable to the role they play in ‘scientific revolutions.’ Most of the time science proceeds in a widening spiral, with new hypotheses consistent with the current theory constantly being explored—a process in which the operator ‘posing structure’ of Indurkhya (1986), and its likes, that I mentioned earlier play a crucial role. But there are occasions when a totally new theory, with a radically new ontology, is called for: an extension of the existing theory will just not do. Kuhn cited at least three such instances from the history of science: the replacement of Ptolemaic astronomy with Copernicus’ astronomy, the replacement of the phlogiston theory of chemistry with Lavoisier’s oxygen theory of combustion, and the replacement of Newtonian mechanics with Einstein’s theory of relativity. On all these occasions, a ‘scientific revolution’ took place, meaning that the scientific community threw away the existing paradigm in favour of a new and radically different one. The new paradigm came from a different metaphor, a metaphor that was not triggered by some existing similarity with the older paradigm.

In everyday language, Lakoff and Johnson (1980, Chapter 22) point out how conventional metaphors are instrumental in constructing our similarity matrix, so to
They argue: ‘Metaphors are based on similarities, though in many cases these similarities are themselves based on conventional metaphors that are not based on similarities. Similarities based on conventional metaphors are nonetheless real in our culture, since conventional metaphors partly define what we find real’. (p. 153, emphasis Lakoff and Johnson’s.)

All this suggests that similarity-creating metaphors are not a peripheral phenomena, but they are the centrepiece of cognition. Consequently, understanding the process underlying them is bound to help in unravelling the mystery that still surrounds many aspects of cognition. Recognizing this, we now turn to present an account of similarity-creating metaphors.

3. An account of similarity-creating metaphors

How do similarity-creating metaphors work? How do they create similarities where none existed before? Where do the newly created similarities come from? Is the creation of similarities purely arbitrary, or is it constrained somehow? In the latter case, exactly what factors constrain them? These are some of the questions we are going to address here. The discussion is kept deliberately informal. For a much more detailed and formal treatment the reader is referred to Indurkhya (1992). The main objective of this section is to impart a clear intuitive understanding of the cognitive mechanisms underlying similarity-creating metaphors so that we may discuss in the next section how these mechanisms might be modelled with existing AI technology.

The thesis that I wish to advocate here is that the mechanism underlying similarity-creating metaphors is a part of the very fundamental cognitive process of conceptualization—that is, the process that creates a conceptual world out of our sense impressions, a conceptual world that we actually ‘see’ in our mind’s eye. In advocating this view, I am going to adopt the following approach. First I will discuss the characteristics of this conceptualization process, and elaborate at some length the cognitive mechanisms that play a key role in it. Then I will argue how one of these cognitive mechanisms can account for similarity-creating metaphors and their characteristics including the creation of similarity. Finally, I will briefly examine some of the implications of this view of metaphor.

3.1. Cognition and conceptualization

We do not live in a world of sense impressions, but in a world of concepts. When I look around, I do not ‘see’ the patterns of activity of the retinal cells in my eyes; I see trees, fields, birds, and rivers. Also, when we act upon our environment, we act upon this world of concepts. We plant a tree, bathe in a river, move a log across the field, etc. Much, if not all, of our cognitive activity consists of converting the kaleidoscopic flux of activity we receive from our senses into a ‘meaningful’ world of concepts—or a phenomenal world as it is sometimes called.

The process of conceptualization sometimes works by grouping, or chunking, aggregates of sense impressions into larger wholes; or, in other words, by reducing the myriad of sense impressions into a handful of concepts and categories. Thus, though every tree might form a different image on our retina, or even the same tree might form different images at different times, we group all these sense impressions together, and label them ‘tree’. At other times, the conceptual wholes are imposed upon the sense
impressions—as gestalt psychology has clearly demonstrated—even when the precise patterns of sense impressions that the wholes represent are not to be found in the sensory data. Thus, when the sensory stimuli consist of two flashes of a dot near each other in quick succession, we ‘see’ a smooth and continuous motion of the dot from the first position to the second. In either case, the result is that we feel and experience the environment as a structured network of concepts: we see a robin’s nest in the tree across the river. Yet, this conceptual world is ‘real’ in very sense of the word: it really is a tree that I see over there, and, if I bump into it, I could hurt myself and feel real pain.

All this, of course, has been known since at least as far back as ancient Greeks. Concepts, or networks of concepts, have been referred to as ‘ideas’ by Plato, ‘categories’ by Kant, ‘schemas’ by Piaget, ‘symbolic systems’ by Cassirer, and ‘worlds’ by Goodman. However, it is only in this century that we have come to realize that the phenomenal world we experience is neither completely determined by some so called ‘transcendental’ or ‘a priori’ structure that is already present in the external world, nor is it arbitrarily structured by the subject. Rather, it comes about as the result of an interaction between the subject and her environment.

The subject affects the structure of her phenomenal world in two ways. First, the physiological and neurological structure of her body and brain puts some very fundamental constraints on how Reality—and I am capitalizing this term to emphasize my usage of it to refer to the mind-independent external world, the Kantian Ding-an-sich—might be perceived. For instance, the cells in the human visual system are configured so that the eye ‘looks for’ straight edges in the visual field. Notice, however, that the neurophysiological basis of cognition is a double-edged sword. While it can be used to provide the basis for linguistic and cultural universals (in the sense that straight edges can be considered a ‘universal’ for humans), it can also, at the same time, be used to affirm the role of the subject in determining her cognitive structures, or phenomenal world (in the sense that it is the structure of the human eye that determines how and what part of Reality is made available for cognizing). Indeed, it is in this latter spirit that Johnson (1987) has emphasized the bodily basis of cognition.

In the second place, within the limits set by one’s physiology, there is still plenty of scope left for exercising one’s creative spirit. All humans, across all cultures, share many physiological features. Yet the diversity of languages, customs, rites, religions, art-forms, etc. among different cultures is amazing. That such myriad of cognitive structures can evolve from the same neurophysiology constitutes pressing evidence that the subject is not merely a bundle of feature detectors, passively recording sense impressions from the environment and adapting her cognitive structures to it. On the contrary, the subject asserts her formative, creative power in shaping her cognitive structures, and directing their growth.

Yet, in all this, Reality does not stand by passively. Individuals, and whole societies, have perished when their cognitive struck a jarring chord with Reality. Affirming the role of Reality in shaping one’s cognitive structures, however, does not force one to admit the existence of some transcendental structures. Reality does not make the subject’s cognitive structures conform to its transcendental structures—assuming some such thing exists—but it would be more accurate to say that Reality constrains the possible phenomenal worlds that can be created by the subject.

Thus, using Goodman’s terminology, cognition consists of creating ‘worlds’ in Reality. All worlds are worlds within a description, worlds from a frame of reference.
The subject gets to play her role in cognition by being able to place the frame of reference arbitrarily. However, once the reference is fixed—the descriptions are made and the ‘meanings’ of the terms of descriptions are fixed—the judgements within that frame of reference are no longer arbitrary. Reality ferociously asserts itself here. One may have spent years of intellectual, emotional and physical energy to formulate an elaborate theory of flying that is internally consistent (does not lead to any logical contradictions) and fully coherent with all the numerous previous observations. Yet, the theory and the dream of flying are easily shattered by the dispassionate and uncaring Reality, as the primitive flying machine plummets to the ground like a dead bird. Reality is oblivious to our notions of consistency or coherency.

3.2. Interaction view of cognition
Assuming this dualistic account of cognition, we next ask: Exactly how does the subject assert her creative power in determining the phenomenal world? Exactly how does Reality constrain the possible choices? A reasonable answer to these two questions is necessary to bring home the interaction view of cognition.

The monumental works of Jean Piaget, a biologist, a philosopher and, most of all, a psychologist, go a long way towards addressing these issues. He posited two mechanisms, assimilation and accommodation, that mediate a subject’s interaction with her environment. Assimilation is the process that reduces the subject’s sensory stimuli to some familiar concept or category. Accommodation is the process that causes the subject to modify her cognitive structures in response to some unexpected or startling stimuli from the environment.

Starting from an essentially Piagetian framework, I have attempted to articulate these two mechanisms of cognition formally in an algebraic framework (Indurkhya 1992). While I have kept the Piagetian term ‘accommodation’, I chose to refer to its counterpart as projection. The main reason for this change is to dissociate the precise sense in which I use the term ‘projection’ from the wide interpretation that is accorded to Piaget’s ‘assimilation’.21 I will now present a brief—and, of course, informal—account of these two mechanisms, which will pave the way to address the questions related to similarity-creating metaphors that we posed earlier. Before doing so, however, I must introduce the notions of ‘concept network’, which is a structured set of concepts; and ‘sensorimotor data set’ which is Reality as seen through the subject’s sensorimotor organs.

3.2.1. Concept networks and sensorimotor data sets (SMDs)
Concepts, while they have a referential function in being able to connect with our sense impressions, nonetheless, enjoy an independent status that allows us to combine them in various ways to generate non-referential conceptual structures. The existence of mathematics, various forms of fiction, etc. clearly attests to this non-referential role of concepts. In this process, however, concepts show an inherent structure that precludes arbitrary combinations. For instance, each of the concepts ‘child’ and ‘parent’ is the converse of the other; and the concept of ‘mother’ is subsumed by the concept of ‘parent’. Another example is provided by the dictionary meanings. A dictionary essentially relates concepts to one another without connecting them to the things in the external environment. Thus, we can talk about concept networks, which are structured sets of concepts. It may be helpful to add here that a concept network corresponds to ‘schema’ of Piaget, ‘schemata’ of Goodman (1976, II, 6, pp. 71–74), and ‘idealized cognitive model’ of Lakoff (1987).
Eleanor Rosch, in one of her landmark papers on cognitive aspects of categorization, astutely noted: ‘the real world is not an unstructured total set’ (Rosch 1978, p. 28). That is, Reality, as it presents itself to us in the form of sensory stimuli that form the raw material for conceptualization and categorization, is already structured in a fashion. For instance, certain sets of stimuli may occur together, while certain others may preclude one another. In fact, it is this structure that constrains the subject from creating arbitrary categories and concepts. I will refer to this structured set of stimuli as the sensorimotor data set, abbreviated as SMD in the rest of the paper.

There are two main characteristics of the SMD that need to be emphasized here. The first is that the ontology of the SMD is brought about by the sensorimotor apparatus of the subject. That is, no a priori ontology exists for Reality. The second is that the structure of the SMD is rooted in Reality and is therefore autonomous in the sense of being independent of the subject. Let me elaborate both these points with an example. Suppose I am standing in front of a tree. It is the biological structure of my eyes that determines what image is formed on my retinas, what contrast I see, what colours I see, etc. (Of course, it also depends on the object in front of my eyes, the lighting conditions, etc. But different objects, or the same object under different lighting conditions, are all considered different stimuli in the SMD.) Similarly, as I walk towards the tree, it is the structure of my motor apparatus that determines what possible movements I can make. However, the effect of any such movement on changing one stimulus on my retina into another, possibly different, stimulus is determined by the structure of the external world. It is precisely in this sense that Reality, while owning its form (as experienced by me) to my sensorimotor apparatus, nonetheless appears as an autonomous external entity to me.

3.2.2. Interaction between the concept networks and the SMDs
Cognition can now be viewed as an interaction between these two structured levels—the level of concept network and the level of SMD. The process invariably works by ‘grouping’ chunks of the SMD and identifying them with the concepts of some concept network. However, since both the SMD and the concept network have autonomous structures, this identification must preserve each of the two structures. I will refer to this structure-preserving property as coherency. Our notion of coherency should not be confused with the internal consistency of concept networks. A concept network may be internally consistent, and yet incoherent with the autonomous structure of the SMD. A person may have an internally consistent network of beliefs that predicts that he can walk on water. But it is the subject-independent structure of the SMD that determines whether that network of beliefs, when put into practice, coheres with the subject’s actual experience.

The process of grouping the SMD into chunks and making a coherent correspondence between the grouped SMD and the concept network, which we will refer to as ‘conceptualization,’ is made possible by an interplay of projection and accommodation. Projection establishes, or alters, the grouping of the SMD by forming, or changing, the correspondence between the concepts and the chunks of the SMD. Accommodation works by altering the structure of the concept network. Although both these mechanisms act in concert to bring about conceptualization, it is possible to explain each mechanism by holding fixed the effect of the other one. Moreover, there are several cognitive acts that are predominantly projective or accommodating—meaning that the conceptualization is brought about primarily by
one or the other mechanism. Consequently, I will explain each mechanism. The reader should keep in mind that in most other situations both the mechanisms might be fairly active.

3.2.3. Accommodation
Let us look at accommodation first. It works by the subject starting out with a grouping of the SMD, and an identification of the concepts with the groups of SMD. This correspondence remains fixed throughout the process. However, the structure of the concept network may not preserve the autonomous structure of the SMD. In this case, the subject responds by altering the structure of the concept network so as to maintain coherency. The process is graphically shown in Figure 2.

Some examples will perhaps be helpful here. Imitation comes to mind immediately as a typical activity that is dominated by accommodation. When one imitates an action, a sound, or a view, one is copying the SMD in a sense. Notice here that any imitation is an imitation only in certain respects. If you were imitating my act of

![Figure 2. A perspective on accommodation. In (a) the subject gives an ontology to the sensorimotor data set. In (b) the autonomous structure of the sensorimotor data set determines the structure of this ontology. In (c) the subject adapts the structure of the concept network to reflect the structure of the sensorimotor data set.](image-url)
touching my nose with my left hand, you will have to decide whether your touching my nose or your nose would amount to an imitation. You will also have to decide if the nose should be touched with my hand or yours and if it should be the left or the right hand; not to mention deciding whether to imitate the place where I was standing or sitting, the direction I was facing, the clothes I was wearing at the time I touched my nose, etc.\textsuperscript{25} In deciding all this you would be asserting your role as a cognitive agent in accommodation. However, once the relevant aspects are decided, the SMD is grouped, and the correspondence is established between the concepts and the chunks of the SMD; or, in other words, the ontology of the SMD has been determined. The SMD takes over from here and you adapt the structure of your concept network to conform to the autonomous structure of the SMD.

As another example of accommodation, consider the map-making process. Here, the subject starts with a predetermined grouping of the chunks of the environment—land, water, park, residential area, street, etc. depending on the purpose of the map—and then adapt the structure of the concept network (the configuration of the map) to the structure found in the grouped SMD.\textsuperscript{20}

These examples help to show why the subject is not entirely passive during accommodation. The process of grouping the SMD and establishing a correspondence between the concepts and the chunks of the SMD is a prerequisite for accommodation. This choice is made by the subject, consciously or not. In many cases the biological structure of the subject may be such that the correspondence is predetermined and cannot be varied at all: the choices are already made by evolution and the subject has no conscious control over it. However, if the subject does have some freedom in this respect—as is the case with some species including us humans—then she is capable of using projection to alter the grouping and ontology of the SMD, which we will discuss now.

3.2.4. Projection
In projection, the structure of the concept network is kept fixed, and it is the grouping of the SMD, and the correspondence between the concepts and the groups, that is altered so as to maintain coherency. Notice that once the subject chooses a concept network to project, since its structure will be kept invariant, we may view the role of Reality as determining the possible groupings, or ontologies, that respect the structure of the concept network. Thus, just as in accommodation the subject was not entirely passive, in projection, Reality is not a passive recipient of the projected structure, but asserts itself by constraining the subject’s choices of ontologies or groupings. This point is graphically illustrated in Figure 3.

The most classic example of projection is the retinal inversion of an image in our visual system. We all know that the image formed on the retina of our eye is actually inverted. However, we do not ‘see’ things upside down. This, of course, is easily explained by the fact that our concept networks already take the inversion into account. In other words, the correspondence between our concepts and the images on our retina is such that the structure of the concept network preserves the structural relationships among the retinal images; and since ‘upside down’ is itself a part of this concept network, it actually corresponds to those images that are upside up. Suppose we now change the structure of our eyes so that the images on the retina are not inverted, a task easily accomplished by wearing proper lenses in front of the eyes. Obviously, it would immediately make the earlier correspondences of our existing concept networks incoherent. This experiment was, in fact, carried out by Stratton
Indurkhya (1897) at the end of the last century. As one might expect, the incoherency resulted in vertigo and nausea. However, after about a week, everything started to appear normal. What might have happened? Surely it is too short a time to ‘relearn’ all the various skills in which the visual stimuli play a role.

The phenomenon is easily explained by the mechanism of projection. In order to ‘see’ everything normal, with the distorting glasses in front of the eyes, all that is necessary is to alter the correspondence between the concepts and the retinal images so that, among other things, ‘upside down’ is now connected to the upside down images. As to be expected, Stratton encountered a similar experience when he took off the distorting glasses: it started out with a feeling of dizziness but after about a week everything was back to normal. One might say that the correspondences were back to what they were initially. This example also demonstrates that not all the correspondences between the concepts and the chunks of the SMD are predetermined for us, thereby allowing us to use the mechanism of projection in conceptualization and making metaphor possible.

Figure 3. A perspective on projection. In (a) the subject selects a concept network with an autonomous structure. In (b) the sensorimotor data set based on its autonomous structure, determines the possible groupings that respect the structure of the concept network. In (c) the subject, in conceptualizing the sensorimotor data set, chooses one such grouping.
Other examples of projection can be found in playful activities of children. When a child identifies a doll with herself, she is essentially projecting her concept network of herself onto the doll. In any such playful activity of children, the interesting thing is that the projection is far from arbitrary, and reveals a systematic structure that the child is attempting to preserve.\footnote{28}

As another example of projection, consider how we use the lines of latitude and longitude. Obviously, these lines do not exist in our environment and so they could not have been induced by it. It is a system of reference that we have developed for our convenience and then projected onto our environment. Similarly, our system for measuring time is an instance of a conceptualization that is primarily generated by projection. Notice here that although one might argue, quite plausibly, that the conceptualization of ‘night’ and ‘day’ is induced by the environment through accommodation, the conceptualization of ‘hour’, ‘minute’, and ‘second’ comes purely from projection. It is also easy to see here that Reality, not a principal actor in projection, nonetheless plays a key role. It is true that we could have chosen another concept network in place of lines of latitude and longitude, but once a network is devised and projected, it is Reality that determines whether two places are on the same ‘latitude’ or not. We could have chosen to divide the day into 43 ‘hours’, but, even then, whether two events took place within the same hour or not would be a matter that was determined by Reality.

3.2.5. \textit{Lateral interactions between two concept networks or two SMDs} It must be emphasized here that both projection and accommodation involve an application of abstract concepts to concrete SMDs. Though, both concept networks and SMDs are internal to the cognitive agent, and, in a sense, both can be considered internal representations of Reality, there is a key difference in that concept networks are highly abstract whereas SMDs are concrete objects that correspond to raw perceptual data.\footnote{29} This point must be clearly kept in mind so as not to confuse the interaction between a concept network and an SMD that occurs through projection and accommodation from the lateral interaction that may take place between two concept networks through mapping and alignment,\footnote{30} which also plays a role in cognition and which, as I will briefly point out in the next section, forms the basis of similarity-based metaphors. To elaborate upon this point, for it is crucial to appreciating the import of this framework and its AI implications, let me say a few words on the lateral interaction that can take place between two concept networks or two SMDs.

In a lateral interaction, both the concept networks are highly abstract. Though, obviously, concepts in a concept network can differ slightly in their degree of abstraction—the concept ‘animal’ is more abstract than the concept ‘cow’, for instance—they do not approach anywhere near the concreteness of the perceptual stimuli derived from seeing an actual cow (or a certain pattern of clouds). In particular, in a lateral interaction between two concept networks, no grouping is involved in the ontology of either of the concept networks. The process, then, is essentially that of comparison; or that of finding some kind of mapping and alignment between the two concept networks.

Although this mapping and alignment process lends itself to cognition in its own ways—in highlighting-downplaying, generalization, etc.\footnote{31} it cannot easily explain how completely new conceptualizations of familiar objects and events emerge as, for instance, in the painting-as-pumping metaphor. Of course, one could take an extreme view to maintain that the lateral interaction between two concept networks is the only...
available cognitive mechanism, and try to somehow explain the creation of similarity within it, as has been done in Gentner and Wolff (1994), but this approach needs to resort to some needlessly contorted explanations as we will discuss later in Section 5.

These observations can be extended to the lateral interaction between two SMDs too—for here again both are highly concrete objects—except with the following caveat. While the concept network, by definition, is a structure that is internal to the subject and that the subject can fully access and manipulate, the SMD does not have this latter requirement. This is especially true of biological cognitive agents, such as ourselves. This point is easily appreciated by noticing that we cannot really ‘see’ the image of a tree on our retina, no matter how hard we try. Of course, there are variations among the individuals as to the lowest level of concrete image that is accessible. For instance, an artist may see the geometrical shapes and the contours in the profile of a face quite clearly that are not seen by another observer. Nonetheless, for any cognitive agent, there may be limitations to carrying out the lateral interaction between two SMDs.

### 3.3. Similarity-creating metaphor as projection

Let us now address two of the questions posed at the beginning of this section. How do similarity-creating metaphors work? How do they create similarities where none existed before? Considering them in the context of Schön’s example of paintbrush-as-pump metaphor, we ask: What does it mean to say that the metaphor created similarities between painting and pumping?

To answer this question, we have to remind ourselves that when we ‘see’ any object or situation, what we really see is a conceptualization of it. Therefore, any similarities, or dissimilarities, between any two objects or situations are always with respect to their respective conceptualizations. Thus, in order for similarities to be created, the conceptualization of at least one of the two objects has to be changed.

So far we are in agreement with Schön’s own account. He argued that the painting-as-pumping metaphor resulted in a completely different way of conceptualizing painting. Even the causal structure was altered. For instance, in the earlier conceptualization, it was supposed that the paint sticks to the surface due to the smearing action. The narrow spaces between the fibres play no role in this conceptualization. However, they are the key element in the altered conceptualization of painting, according to which the paint is sucked into these inter-fibre spaces due to capillary action, and is squeezed out due to an increased pressure when the fibres are bent in the painting process. This point, namely that similarity-creating metaphors work by changing the conceptualization of one of the objects involved, has also been noted by Gerhart and Russell (1984).\(^{32}\)

So the problem now is to explain how the change in conceptualization is brought about. To address this, I will make use of the terms ‘source’ and ‘target’ that were mentioned at the beginning of the paper. In painting-as-pumping metaphor, painting is the target and pumping is the source. Now in the light of the account of cognition and conceptualization I presented earlier, I must also bring in the terms ‘concept network’ and ‘SMD’. Since these latter terms make a distinction that is orthogonal to the distinction introduced by the former terms, we end up having ‘source concept network’, ‘source SMD’, ‘target concept network’, and ‘target SMD’.

Which of these four components are involved in creative metaphors? Well, we have already seen that the creation of similarity results from the reconceptualization of the
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target. It means that the target SMD must be one of the participating components, which is grouped anew into concepts. As far as the source is concerned, its role is to provide a structure of concepts to affect the grouping of the target SMD. This suggests that the source concept network is the other participant in the process. A similarity-creating metaphor, thus, works by reconceptualizing the target SMD according to the structure of the source concept network. The process is graphically shown in Figure 4.

To see that this articulation of similarity-creating metaphor is nothing but projection in disguise, we need only note that it is the grouping of the target SMD—that is, its ontology as seen from the conceptual level—that is changed in the process. The structure of the source concept network is usually not altered. (Except in the sense that through the increased usage of the metaphor, the concepts in the source concept network acquire a new meaning in the context of the target SMD, with a corresponding adjustment in the concept network to reflect this change of meaning.) So we may view the process underlying similarity-creating metaphors to be essentially that of projecting the source concept network onto the target SMD.

This account of metaphor, and how it creates similarities, can be better elucidated with the example of Figure 1 we introduced earlier. Suppose that the conventional (or literal) conceptualization of the figure of Star of David in a culture was based upon seeing it as two equilateral triangles (Figure 1(b)). Now when someone compares it with Figure 1(c), which is conventionally conceptualized as a hexagon with an osculating circle on each side (Figure 1(a)), initially there are no similarities between the two figures. Then, after a moment of introspection a flash of insight occurs. Aha! The conventional conceptualization of the figure of Star of David is replaced with a new one that sees it a hexagon with an equilateral triangle on each side (Figure 1(e)). Now there are similarities between the two figures.

This reconceptualization of the figure of Star of David essentially results from projecting the concept network corresponding to ‘a hexagon with an osculating circle on each side’ onto the SMD corresponding to the Star of David that is structured, say, in terms of line segments. In the process, the lines in the Star of David are grouped differently than in its conventional conceptualization. We now find the concept of ‘hexagon’ in it. ‘Osculating’ the hexagon are figures of triangles (or two lines in the shape of ‘V’). Notice that we do not find any ‘circles’ in there, and therefore there is only a partial similarity between the source and the target afterwards. In fact, this example points out how the target SMD does not passively allow arbitrary regroupings but, as Goodman has described figuratively, protests while yielding.

3.4. Implications of the received view of metaphor

The account of metaphor presented above has some interesting consequences. I will briefly comment here on some of the more prominent ones.

3.4.1. Asymmetry of metaphors

Our account of metaphor explains an observation of Lakoff and Turner concerning the asymmetry of metaphors:

When we understand that life is a journey we structure life in terms of a journey, and map onto the domain of life the inferential structure associated with journeys. But we do not map onto the domain of journeys the inferential structure associated with the domain of life. For example, we do not understand thereby that journeys have waking and sleeping parts, as lives do. We do not infer that, just as we can lead only one life, so a traveller can take only one journey. We map one
Figure 4. For caption see opposite.
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As long as a metaphor is regarded as a mapping from the source 'domain' to the target 'domain', this 'one-way mapping' explanation of the asymmetry does not make sense. Since 'domains' are associated with the 'inferential structure', they must be identified with the concept networks. But then, what would be a 'one-way mapping' from the source concept network to the target concept network? How is it different from a 'two-way mapping'? (The reader may consider different ways of formalizing 'domains' and try to figure out what do the terms 'one-way mapping' and 'two-way mapping' mean in the formalization.)

In the account of metaphor presented here, with the distinction between the concept network and the SMD, this asymmetry is easily explained without resorting to some vague concept like 'one-way mapping'. When the source and the target are reversed, it would be the target concept network that would be projected on the source SMD. Each of the two components of the projection process being different, it is not the least bit surprising that the result should be different also.

3.4.2. The role of target concept network
In taking projection to be the process responsible for similarity-creating metaphors, it may appear that the target concept network and the source SMD do not play any role. However, this is not always so. Although truly creative metaphors work by disregarding the existing conceptualization—as reflected in the target concept network—of the target SMD, often the target concept network, or a part of it, may mediate the reorganization of the target SMD by the source concept network. Since the source and the target concept networks are both highly abstract, the lateral interaction between them is essentially comparative. Thus, the resulting metaphors are what we have called similarity-based metaphors, since they are based on the existing similarities between the source and the target concept networks. The role of the target concept network in this interaction can range from complete mediation on one hand, to merely providing an initial grouping and ontology to the target SMD—based on which additional structure from the source concept network may be imported to further organize the target SMD—on the other. I have discussed these two modes of metaphor, referring to them as 'syntactic metaphor' and 'suggestive metaphor' respectively, at length elsewhere (Indurkhya 1991a, 1992).

3.4.3. The role of source SMD in creating similarity
As far as the role of the source SMD is concerned, it brings us to another question we posed earlier: Where do the created similarities come from? Clearly, the creation of similarities is not an arbitrary process. We may choose to project any concept network

Figure 4. Similarity-creating metaphor. (a) Before. The source and the target concept networks group their respective sensorimotor data sets quite differently. There are no existing similarities between the two! (b) After. The structure of the target sensorimotor data set is regrouped so as to reflect the structure of the source concept network. Now there are similarities between the source and the target. (Note that not all parts of the source concept network need be used.)
on an SMD, but the resulting conceptual organization of the SMD does not always fulfill our expectations. For instance, in the paintbrush example discussed above, Schön noted that in trying to get a fresh perspective on the process of painting—a perspective that can explain the poor performance of the synthetic fibre paintbrush—the researchers tried to conceptualize it in several other ways. They tried to think of painting as masking-a-surface with no useful results. What, then, makes a source concept network more successful than others? For an answer we must look towards the source SMD, which is the SMD that is ‘conventionally’ conceptualized by the source concept network. It provides a plausible explanation to the origin of the created similarities.

Reality, the Kantian Ding-an-sich, is richly connected. We might even say that it is totally connected: given any two objects, one can always find some way of relating them to each other, and find something that they have in common. It is only our perceptual and cognitive apparatus that groups Reality into chunks and imposes—subject to the constraints of Reality—the structure of our concept networks on them. However, in carving up two SMDs in this fashion—that is, in imposing a conceptual structure on each of them—this connectivity is lost. The SMDs, viewed through their respective concept networks, are no longer seen as similar. However, in projecting the source concept network, which might have originated through an interaction with the source SMD, onto the target SMD, this connectivity is partially recovered, as the subject is forced to regroup the ontology of the target SMD to create one that is partially isomorphic to the source concept network. This is what Schön had in mind when he wrote in connection with the paintbrush-as-pump metaphor:

It is important to note that the researchers were able to see painting as similar to pumping before they were able to say ‘similar with respect to what’. At first, they had only an unarticulated perception of similarity which they could express by doing the painting and inviting others to see it as they did, or by using the terms like ‘squeezing’ or ‘forcing’ to convey the pump-like quality of the action. Only later, and in an effort to account for their earlier perception of similarity, did they develop an explicit account of similarity, an account which later still became part of a general theory of ‘pumpoids’, according to which they could regard paintbrushes and pumps, along with wash-cloths and mops, as instances of a single technological category (1979, p. 260).

In other words, there are similarities between the SMDs of painting and pumping. Similarities that are lost in grouping the SMD of painting as a smearing process. And it is these similarities that are discovered by the metaphor—or perhaps we should say ‘rediscovered’.

3.4.4. Cognitive force of similarity-creating metaphors

This account of similarity-creating metaphors also explains why they are such an invaluable asset to cognition. Cognition typically involves grouping. Various parts of Reality that are made available to us by our perceptual and motor apparatus (in the form of SMD) are further grouped into categories and concepts. Thus, the ‘world’ as seen from the cognitive level is considerably more simplified and structured than the one seen from the lower perceptual level of SMD. This simplification is perhaps necessary to allow us to survive in an infinitely complex Reality with our finite and limited minds. However, an act of grouping invariably involves loss of information. In putting a bunch of different stimuli in a category, their individual differences are overlooked: one might say that they are lost by the process of cognition. When we identify two different visual stimuli as ‘cows’, their differences are overlooked. Similarly, in putting two stimuli in different categories, their similarities are lost as well. In grouping the SMD in one way, though the resulting simplified world view
makes it easier for the subject to interact with her environment, she is deprived of a horde of alternative world views.

Now if the conceptualization process were rigid and unchanging—for biological or cultural reasons—then the lost worlds are lost forever. The parts of SMD that are fused together in the same concept remain fused forever. The subject can never recover the information lost in cognition and reorganize her world views.

However, if the subject can project different concept networks onto the same SMD, she can partially recover these lost worlds. Some of the distinctions between different parts of the SMD that are lost as a result of the groupings induced on it by its ‘conventional’ concept network can be made visible again under the ‘regrouping’ induced by another concept network. Thus, metaphor allows the subject to partially reclaim the loss of information that inevitably results from cognition.

At times the alternate conceptualization provided by the metaphor may be crucial in solving a particular problem, as in Schön’s example of paintbrush-as-a-pump metaphor. At other times, the sheer intellectual and emotional pleasure derived from a glimpse of the ‘world’ that might have been may be the sole reason for the appeal of the metaphor, as is the case with most creative metaphors in art and literature. In either case, it is the partial recovery of lost perceptual information that give similarity-creating metaphors their cognitive force.

3.4.5. Homomorphism versus isomorphism

In articulating his account of the interaction theory of metaphor, Black (1955, 1977) proposed that underlying every metaphor is an isomorphism between the source and the target. Since then, though many researchers took up the idea that some kind of mapping between the source and the target is the basis of a metaphor, the isomorphism condition has been dropped by just about everybody for two reasons. First, it is pointed out, the metaphorical mappings are almost always partial. Secondly, it is argued, the mappings are often many-to-one. Consequently, Black’s isomorphism condition is replaced by the much weaker condition of partial homomorphism.

Our account of metaphor, however, reaffirms Black’s original proposal. In Figure 4(b), for example, the regrouped target SMD is drawn isomorphic to the source concept network. This may seem counterintuitive at first. For if we see the shape of kangaroos in the clouds, we do not actually see kangaroos floating in the sky.

This apparent paradox is resolved by pointing out that because we incorporate the conceptualization process itself in our account, we can allow a cognitive agent to have several conceptualizations of an SMD. Moreover, these different conceptualizations, while being highly abstract, can still occupy different levels of abstraction, and the cognitive agent can access them dynamically, altering them and creating new conceptualizations in the process. As a result, our account readily allows a cognitive agent to be perceptually aware of several things, and yet to ignore them at a conceptual level. For example, when a cognitive agent sees a cow, it may be aware of many perceptual features of the cow, but it can focus on some of them, group them together in a certain way, and produce a description ‘I see a cow’. The point is that not every perceptual feature in the SMD has to be included in the conceptualization or be verbalized. Moreover, the cognitive agent may also be aware of some other possible groupings and conceptualizations that are not included in the verbal description (for instance, that the cow is big and is white with black spots). But we certainly do not require that the cognitive agent must generate all possible conceptualizations: on the contrary, we believe that such a requirement is far from realistic.
The same can happen with metaphors and analogies. A cognitive agent can choose to ignore many perceptual features of the cloud (and of kangaroos), and focus only on the shape, to see kangaroos floating in the sky. Of course, the cognitive agent can also choose to include some of the ignored information in its description anyway, like in saying ‘I see the shape of a kangaroo in the clouds’. (Compare it with ‘I see a big white spotted cow in the field’.)

Or, consider using the map of a city to navigate oneself. Clearly, the map does not represent everything in the city. Yet, in using the map, one gives the city an ontology where parts of the city are grouped together and seen as primitives. For instance, the two lanes of a street, the sidewalks, and the shops and the buildings along the street are all seen as one unit, represented by a line on the map. Thus, one acts as if the map, an analogical representation of the city, is isomorphic to the city, even though the street is not painted red but its corresponding line on the map is, and vehicles on the street are nowhere to be found on the map. The point is that we can move flexibly between different conceptualizations, and in metaphors, in creating a new representation, a level of conceptualization exists where the target SMD is seen as identical to that part of the source concept network that applies to it. This level of conceptualization, in our account, epitomizes the cognitive force of metaphor. But this is not to say that the cognitive agent has completely lost all other perceptual or conceptual awareness of the target SMD.

4. Implications for AI models of metaphor

Let us now examine how the process underlying similarity-creating metaphors might be modelled with existing AI technology. According to the account of similarity-creating metaphors I presented above, the underlying process is essentially that of projection. So in order to model creative metaphors, we have to be able to model projection.

To this end, I will start by arguing, in Section 4.1, that projection is not something new to AI, and there exist AI systems that incorporate this mechanism, though it is not called as such. This observation would naturally lead us to the question: Is any AI system, capable of projection, also capable of producing similarity-creating metaphors? I will answer this question in Section 4.2 by pointing out that not every projection is metaphorical, but only ‘novel’ projections are. Finally, in Section 4.3, I will outline how an AI system can model similarity-creating metaphors.

4.1. Projection as ‘top-down’ grouping

Recall that projection is the process of integrating the SMD into a given concept network, such that the structure of the concept network is kept invariant, but the correspondence between the concepts and the chunks of SMD—or, in other words, the grouping or ontology of the SMD—is altered. Now in order that we may seek an equivalent mechanism, if one exists, in the domain of existing AI systems—or even non-AI computational systems—we must first determine what a concept network and an SMD refer to in the context of any such system.

As I emphasized earlier, the difference between an SMD and a concept network is essentially that the concept networks are highly abstract and SMD are concrete objects. Now there are many computational systems in which the concrete input data, in the course of processing, is organized in terms of the abstract concepts that are implicitly or explicitly provided to the system. For instance, consider a parser for any...
formal language, one of the commonplace computational systems. The input to the parser is a string of symbols. Assuming that the string is well-formed in the formal language, the parser would end up representing it as a parse-tree (or more than one, if the language is ambiguous). Here, the parse-tree is clearly an abstract representation of the concrete input string. In general, a parse-tree would correspond to many more input strings than the other way around. Also, the syntactic categories or the non-terminals of the language usually correspond to many different strings of symbols. Thus, the grammar of the formal language can be thought of as the concept network and the input string of symbols as the SMD. The process of parsing, then, is essentially that of integrating the SMD (the input string) into the abstract structure of the concept network (the grammar of the language). But this is precisely what we have called conceptualization in the previous section.

Indeed, as simple and commonplace as this example of a parser is, it helps to illustrate many, if not all, aspects of the conceptualization process in a computational setting. For instance, notice that the input string, the SMD, is independently structured. The order of the symbols in the string is something that the parser cannot alter. At the same time, the structure of the language, the concept network, is also autonomous. It does not depend on the input string. The interactive nature of the conceptualization process is also clearly brought out in this example, for the parse-tree corresponding to any given input string is truly determined in part by the structure of the language and in part by the structure of the string.

This example also helps to highlight the difference between the processes of projection and accommodation. Projection corresponds to the ‘top-down’ grouping in which the rules of the grammar, the concept network, are kept invariant but the grouping of the input string—which groups of symbols are assigned to which non-terminals—is altered to maintain coherency. Note here that coherency refers to matching the structure of the grammar to the structure of string; or, in other words, to parseability.

It must be emphasized that my use of the term ‘top-down’ here is quite different, hence the quote marks, from its traditional usage in the context of parsing as well as many other computational systems. In parsing, for instance, the terms top-down and bottom-up refer to two different strategies that may be used to determine whether the input string can be made to correspond to the grammar of the formal language. In the top-down strategy, one applies the rules of the grammar in a certain order to enumerate parse-trees, checking at each step to see if the current parse-tree corresponds to the input string. In the bottom-up strategy, on the other hand, one starts with the input string, and produces all possible partial parses of it until a complete parse-tree is produced. However, in our sense, both these strategies will be called ‘top-down’ processes. The reason being that even in the bottom-up parsing, the input string is being integrated into the structure of the grammar, or in other words the SMD is being organized in terms of the concept network.

A ‘bottom-up’ approach in our sense corresponds to the mechanism of accommodation. Recall that in accommodation the ontology and the grouping of the SMD is fixed, and it is the structure of the concept network that must conform. In the context of the parser, it means that the input string is already grouped in certain ways, and the goal is to make the structure of the grammar so that the input string is parseable. This is precisely what the grammar learning algorithms set out to achieve. The process of accommodation, thus, is manifested in various machine learning systems.
Our focus of interest here being the mechanism of projection, it must be noted that the corresponding ‘top-down’ grouping is performed by many computational systems. A scene-analysis system that produces a verbal description, or a semantic-net-like representation, of an image from its representation in the form of an array of pixels and their attributes, is essentially carrying out a projection by grouping the pixels and making the ‘groups’ correspond to the abstract concept like ‘house’, ‘roof’, etc. A medical diagnosis expert system, in producing a diagnosis from the symptoms, is projecting the concept network of diseases onto the set of given symptoms. When a story-understanding system organizes the narrative information in the story as a frame or a script, it is essentially projecting the concept network that is the frame or the script onto the concrete SMD that is the text of the story.

4.2. Novel and conventional projections
Given that many computational systems are capable of projection, coupled with the thesis that projection is the process underlying metaphors, we naturally ask: Can a computational system capable of projection also produce creative metaphors? To answer this question we have to remind ourselves that not all projections produce metaphors, but only novel projections do. That is, to recognize a body of clouds in the sky as ‘clouds’ also involves projection, since one has to group the perceptual field appropriately and link it with the concept ‘clouds’ in order to make the recognition. This act of recognition, however, is not metaphorical since the grouping, as well as the association of the grouping with the concept, is conventional. But to recognize in the body of clouds a ‘kangaroo’ is a novel projection, and would be considered metaphorical.

So to answer the question above, we first have to distinguish between conventional and novel projections in the context of computational systems. Notice that this distinction cannot be made on the basis of familiarity with the stimulus. That is, we cannot say that the first time a parser encounters a sentence, its recognition amounts to a novel projection. This would be like arguing that the first time I see a cow I have never seen before, and recognize it as a ‘cow’, I produce a creative metaphor.

Before addressing this issue in a computational setting, let us see how the corresponding problem of separating the metaphorical from the literal (or conventional) is addressed in the context of human cognition. One approach is to assign ‘conventional’ referents (which are SMDs, or grouped chunks of them, in our terminology) to all the concepts. Indeed, most of our sensory stimuli we automatically assign to certain concepts for biological or cultural reasons, as in recognizing a certain visual stimulus as a ‘cow’ almost effortlessly. It merely reflects the intersubjective everyday usage of the concepts in any given society. Note that our term ‘conventional’ here includes both the literal and conventional metaphorical (Lakoff 1986). Even certain standardized indirect speech acts (Searle 1975) such as irony by exaggerating the opposite, or making a request by asking a question, etc. are to be included in our ‘conventional’. I am deliberately ignoring these finer distinctions that can be made among the conventional referents of a concept, because our primary interest here is in creative metaphors.

Given the conventional referents of the concepts, any projection that associates a concept with a chunk of the SMD that is not the conventional referent of the concept can be dubbed ‘novel’. Indeed, this dual or split reference—one conventional and one sustained by the novel projection—is sometimes touted as the most characteristic feature of metaphors (Ricoeur 1976).
Notice, however, that this method of distinguishing between the conventional and the novel projections requires the God’s eye-view of the external world and the subject. This is because when I see something and recognize it as a ‘horse’ to determine whether this projection is conventional or novel I need to have access to the conventional referents of ‘horse’, but the conventional referent of ‘horse’ includes all those SMDs that I have interacted with, will interact with, might have interacted with, etc. While in computational systems the designer or the user of the system has the necessary God’s eye-view, for cognitive modelling of similarity-creating metaphors one must be able to characterize novel projections without resorting to God’s eye-view.

While I have addressed this problem elsewhere at length (Indurkhya 1990), for our purpose here we only need to note that since the concepts are internal to the subject and fully accessible, if the notion of ‘conventional’ is introduced from the point of view of conceptualization, then no God’s eye-view is required. Thus, given an SMD, a certain conceptualization of it is dubbed ‘conventional’, and any other conceptualization of it would then be called ‘novel’. Moreover, it is the subject herself who decides which conceptualization is conventional. For instance, when I look at clouds and see a kangaroo there, what makes it a novel projection is the fact that I am aware, at the same time, that it is clouds, which is the conventional conceptualization of the SMD. In this way the split-reference characteristic of metaphors is turned into that of split-conceptualization.

It must be noted, however, that this only covers those novel projections that have been termed as ‘making the familiar strange’ by Gordon (1961, pp. 35–36). There is a familiar, the conventional, conceptualization of the SMD. Then in making a novel projection with another concept network, the familiar SMD is made to appear strange. There is another class of novel projections, corresponding to Gordon’s ‘making the strange familiar’, in which there does not exist any conventional conceptualization of the SMD, and therefore any projection is novel. In fact, it is precisely in this sense that all works of abstract and conceptual art are considered metaphorical (Fox 1982).

To include this other kind of novel projections, the subject needs to be able to deem certain SMDs as non-conceptual, and for those any conceptualization would be a novel projection, and hence metaphorical. For instance, looking at the blotches of paint on a canvas I have to be aware at some level that they do not fit any of my concepts normally in order that I may dub its conceptualization as ‘the current state of humanity’ metaphorical.

Let us now apply these insights to computational systems, so that we may see which systems are capable of making novel projections, or metaphors, and which are not. Since we have already talked a bit about parsers, let me begin by considering the example of a parser for Natural Language, say a fragment of English. We have already noted that when the parser produces a parse-tree (or a set of parse-trees) when presented with a well-formed expression or sentence of the fragment, it is essentially projecting the concept network that is the grammar of the fragment onto the SMD that is the input expression. Now each of these projections has to be dubbed conventional, whether we consider it from God’s eye-view or the parser’s eye-view, because the correspondence between the parts of the input expression and the syntactic categories of the grammar is both something intended by the designer of the parser and something that the parser naturally comes up with.

We then ask: Can such a parser ever produce a novel projection? Let us see. Consider first the possibility of ‘making the familiar strange’. That is, for an input
expression that can be parsed by the parser we ask whether it can be parsed in a non-
conventional way. The answer is negative because the groupings of the input
expression and their correspondence with the non-terminals of the grammar is fixed by
the grammar and built into the parser. It is as if the projection mechanism is hard-
 wired in the parser, for given any expression there is only one unique way to integrate
it into the concept network of the grammar.
I must emphasize that I am not talking about ambiguities here. Any reasonable
parser for a natural language is bound to have ambiguities—in fact, this is why I chose
the example of a parser for a natural language rather than a formal language. But all
the ambiguities are already a part of the grammar, at least in the way I am envisioning
this parser. The word ‘deep’ may enter into different combinations with the other
words of the sentence, but it would not correspond to the word ‘peep’. This point may
be appreciated in another way by considering the fact that in everyday language we
often use ambiguous expressions but their dual or multi-fold conceptualizations are
not termed metaphorical. For instance, ‘Can you drive?’ can be a genuine query or an
indirect request, but both these conceptualizations of it would be called conventional.
Given that there is no possibility of having a dual conceptualization here, let us
explore the other alternative for creating novel projections, which is to have the parser
project its concept network onto those SMDs for which no conventional con-
ceptualization exists. This amounts to parsing a sentence outside the fragment for
which the grammar was written, by using the same grammar rules. But any such
attempt would result in an abrupt ‘illegal syntax’ or ‘word not in the lexicon’
response. Thus, we find our parser quite incapable of producing novel projections.
The reason for this failure is that a parser works in a noise-free and definitive
domain. A word is either a member of the lexicon, or is not—there is no in-between.
And when it is a member, there is no doubt as to what it is (notwithstanding
ambiguities, of course). Does this mean that if we modify our example to work in a
noisy and uncertain domain, it would be able to generate novel projections? Let us see.
There are several examples of AI systems which typically work on a noisy domain:
speech understanding systems, machine vision systems, handwriting recognition
systems, just to mention a few. Since I started with the parser, let me choose a speech
understanding system, say Hearsay-II, as the example of a computational system
that has a ‘top-down’ mechanism and that works in a noisy domain. Hearsay-II is an
AI system which recognizes spoken English (a subset of it, to be precise). A person
speaks in front of a microphone and Hearsay-II produces a written version of the
speech. The environment is typically noisy: there are individual variations, accents,
presence of other sources of sound, reflected sound from the surrounding objects, etc.
To contaminate the speech. To recognize speech amidst all this noise, the system
makes several assumptions about what the speech is likely to be. This bias is reflected
in the organization and the rules of the system. The important thing to note with this
example is that there is no pre-established correspondence between the acoustic
pattern received from the microphone and the lexicon of the system.
Now to give the system a capability of producing novel projections, suppose that the
speech recognition system has two modules: one containing the rules for recognizing
a subset of English and the other containing the rules for recognizing a subset of
French. Each of these sets of rules forms a concept network. Now suppose that the
system is presented with an acoustic pattern from the microphone, which it recognizes
as some sentence in French. That, then, becomes the conventional conceptualization
of the input pattern. But what if we were to force the system to recognize the input
pattern using the rules of English. While in most instances the system will probably fail, it is possible that at least in some instances, especially when there is much noise contaminating the utterances, something meaningful might result. When it does, it amounts to a novel projection since the English conceptualization of the French utterance is non-conventional.

You might also consider two other modules, one for recognizing conversation pertaining to real-estate business and the other about the stock market, instead. It is not an uncommon experience that in a noisy environment, such as a party, on catching fragments of a conversation what we make of it very much depends on what we think is being talked about. On being informed otherwise, there is invariably a ‘regrouping’ of the same perceptual data. To my mind, this is no different from the ‘regrouping’ of the pattern received from the microphone that takes place when a system such as Hearsay-II decide to use English rules instead of French; or the ‘regrouping’ that takes place in our perceptual apparatus when we try to ‘see’ the process of painting as pumping instead of smearing.

The obvious conclusion to be reached here is that there exist computational systems that are capable of producing novel projections and instances of creative metaphors. A handwriting recognition system that interprets a child’s doodling as characters is producing a creative metaphor. A machine vision system, designed to recognize houses, if on being presented with a picture of camel interprets it as some sort of house is essentially carrying out a novel or metaphorical projection. Note that all these novel projections are not arbitrary; that is, the SMD is not a passive receptor of projections, but constrains the possible conceptualizations. In recognizing a child’s doodling, the system will invariably zoom on various ‘objective’ features of the doodling and ‘see’ them not only relevant, but a key to the identification process. In this way a well-designed system of sufficient complexity can quite impress its human designers by producing interesting conceptualizations when operated in domains other than the ones for which it was intended.

4.3. Modelling metaphor as change of representation

The discussion of the previous two sections suggests an architecture to model similarity-creating metaphors. The central idea is to model the underlying process as change of representations. The model will have concept networks which represent SMDs. For instance, on being presented with a bit-map image of a house, a machine vision system may represent it internally as a network of ‘roof’, ‘wall’, ‘door’, ‘window’, ‘yard’, ‘fence’, ‘driveway’, etc. The SMD is the bit-map image, and ‘roof’, ‘wall’, etc. are concepts of the concept network. In representing the image in this way, the machine vision system would have to instantiate the concepts by identifying them with the appropriate regions of the image. This essentially amounts to projecting the concept network onto the SMD.

When the model encounters any SMD, it immediately seeks to represent it in terms of its concepts in some way; just as we are automatically organizing and filtering our sense-impressions to see instantiations of the concepts in our environment. The representation of an SMD that the model settles to, without any outside factor affecting it, we would call the ‘conventional’ representation of the SMD. Now the instances of similarity-creating metaphors can be produced by forcing the model to change the representation of the SMD from the ‘conventional’ to a ‘novel’ one. The model can be forced to do this by limiting the set of concepts and concept networks it has available for representing the SMD.
Thus, the set of concepts or concept networks that system is being forced to use become the source, and the SMD that is being conceptualized becomes the target. The model would work by producing a conceptualization of the target SMD in terms of the source concepts. The resulting representation would be metaphorical, if it is something that the system would not have produced by itself when the source is not explicitly given.

The architecture of a computational system based on this approach is shown in Figure 5. The key difference between the concept networks and SMDs, namely that concept networks are highly abstract and SMDs are concrete objects, must be emphasized once again. To clear away any remaining confusion let me elaborate, in the context of this architecture, how similarities are created by novel projections, and why it would not do to have the target be presented as a concept network or the source as an SMD.

Consider a machine vision system for recognizing objects. It accepts bit-map image from a camera and produces semantic-net type of representation of the input image. It has two concept networks: one for recognizing animals and the other for recognizing houses. The former has concepts—which are essentially semantic-net primitives—like ‘horse’, ‘camel’, ‘trunk’, ‘hump’, ‘legs’, ‘head’, etc. The latter has concepts such as ‘roof’, ‘chimney’, ‘wall’, ‘door’, ‘yard’, etc. Now on being presented with the image of a camel, the system recognizes it as such, and represents it as a network of concepts from the ‘animals’ concept networks. It would record the fact that it has a ‘hump’, a ‘neck’ which is ‘long’, ‘legs’ which are ‘four’ and are ‘long’ and ‘skinny’; its colour is ‘ochre’, etc. All these concepts are identified with the appropriate regions, or the attributes of the regions, of the image in the process of recognition. This is the conventional representation of the input image.

Now if one compares this representation with some previously stored representation of a house, there would be no similarities between the two. The reason is that from the concept networks' point of view, animal concepts are very different from house concepts. Even structurally, one uses very different regioning and labelling techniques for identifying an animal than a house. However, if the system is forced to 'see' the image of the camel through the concept network of 'house', then the same SMD is
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completely reorganized. Different regioning and labelling routines will take over and try to identify the image as a house. The hump of the animal might be labelled as ‘roof’, and the neck as ‘chimney’. This regrouping forces the similarities between the image of the camel and a house, similarities that were not there between their respective ‘conventional’ representations.

This example also demonstrates why it is necessary to have access to the unrepresented, unlabelled, ungrouped image of the target. Since if only the target concept network is accessible, then only the existing similarities between it and the source concept network can be gleaned. To create similarities, one has to have access to the concrete form of the target object so that it can conceptualize anew—represent differently.

Similarly, if the source concept network is not provided, and only an unrepresented source object is given, then one may not be able to find any similarities at all. For instance, if one is given only the bit-map images of a house and a camel, not much can be gained by a bit by bit comparison of the two images. In fact, if the images were of two very similar houses, even then little can be learned from a bit by bit comparison of the images. The reason for this is that it is the concepts that make us see things as similar. It is the concept ‘triangle’ that makes us see two otherwise very dissimilar figures as alike. It is the concept ‘house’ that makes us see an igloo and a mansion as similar. Thus, it does not help to do away with the concept networks altogether and always try to find similarities between the SMDs corresponding to the source and the target.

Having clarified these points, let us turn back to the architecture of Figure 5. One thing to notice is that it is not necessary, or even suggested, that the conventional conceptualization be determined for each SMD. Given the source concept network and the target SMD, the system would directly project the source onto the target. Computing the conventional representation of the target SMD is not needed at all in this process. Only if the system is explicitly asked whether the projection is an instance of creative metaphor, then it would have to figure out the conventional representation of the target SMD and compare it with the conceptualization in terms of the source concept network. In this sense, as long as the source is provided, the system does not invoke different processes to compute conventional projection and novel projection. In fact, one might say that in a sense the system is not even aware whether the projection is conventional or novel.

The second thing to notice is that by taking ‘conventional’ to mean the representation of the SMD to which the system naturally settles, I am limiting the sense of ‘novel’ to include only ‘making the familiar strange’; and leaving out those novel projections that result from conceptualizing the SMDs that have no natural conceptualizations, corresponding to ‘making the strange familiar’. Thus, when a machine vision system that is designed to generate conceptual representation of house scenes, on being presented with a picture of a camel comes up with a representation of it in terms of house-related concepts like ‘roof’, ‘chimney’, etc., this representation will be termed ‘conventional’, and hence non-metaphorical, according to our characterization. While this may seem odd to some readers, one needs to note that as far as the machine vision system is concerned, it is indeed a house that it ‘sees’ in the camel-picture. It knows of no other conceptualization of that image. It is only we, having the God’s eye-view so to speak, and being fully aware of another more conventional conceptualization of the camel-picture, who see the machine vision system’s representation of the camel-picture as novel and hence metaphorical.
Indeed, this precise point, made in the context of human cognition, is the theme of Colin Turbayne’s excellent *Myth of Metaphor*. Turbayne argued that what we regard as the ontology of the Reality is only a projection, albeit a conventional one, of our concept networks.\textsuperscript{40} However, when we overlook this fact, and take our conventional projections to be the unique immutable ontology of the Reality, then our view of Reality becomes nothing but a myth. The inability of the machine vision system to see beyond its concept network only demonstrates this point more clearly.

For a computational system to be able to regard certain SMDs as ‘strange’ or non-conceptualizable, and yet be able to come up with some reasonable conceptualization when the source is explicitly given, would require a certain degree of self-awareness. Perhaps one way to incorporate this feature would be to have the system generate a confidence factor, along with the conventional conceptualization, when presented with an SMD. A low confidence factor, then, would be taken as the sign to mean that the SMD is ‘strange’, and therefore any conceptualization of it is metaphorical.

5. Conclusions: what similarity-creating metaphors tell us about cognition

The main import of this paper has been to present an account of similarity-creating metaphors that sees them as arising out of the fundamental cognitive process of conceptualization. The key to our approach is the distinction between the concrete SMD and highly abstract concept networks, and the process of interaction between these two levels that tries to preserve the autonomous structures of both levels, while making the concepts correspond to the stimuli in an SMD. In metaphor, the structure of the source concept network is kept invariant, while the grouping of the target SMD and the correspondence between these groups and the concepts of the source concept network is varied. Or, in other words, the representation—as seen from the highly abstract concept network layer—of the target SMD is changed so as to be isomorphic to a part of the source concept network. The similarities between the source and the target concept networks, thus, are created by the metaphor, for the similarities are with respect to the new conceptualization of the target SMD, and if it were not for the metaphor, there might have been no new conceptualization of the target SMD.

With this view of similarity-creating metaphors, I argued that its underlying mechanism of projection is already incorporated in the existing AI systems. Many machine vision systems, handwriting recognition systems, speech recognition systems, etc. incorporate the ‘top-down’—the quote marks are to emphasize the difference in meaning from the traditional use of the term—component whereby the concrete input datum is forced into the existing concept networks. In fact, some of these systems are also capable of coming up with novel and creative ways to conceptualize an unfamiliar datum, a process that is akin to creative metaphors.

Against the backdrop of this discussion, I proposed how creative metaphor can be modelled as change of representation.\textsuperscript{41} The idea is that when the source concept network is explicitly given, the system is forced to conceptualize the target SMD using only those concepts. This may result in a changed representation of the target SMD—changed from what the representation might be when the source is not given—thereby creating similarities between the source and the target.

It is instructive to highlight one crucial implication of our approach that distinguishes it from the majority of other approaches to metaphor and analogy in cognitive psychology and artificial intelligence: namely its explicit recognition of the key role played by the conceptualization process in cognition. In almost every theory or
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model of analogy and metaphor, one starts out with the representations (of the source and the target) as given, and try to explain various cognitive characteristics of metaphor and analogy in terms of mapping and alignment between the given representations. Though we do not deny that some characteristics of metaphor and analogy can be accounted for by mapping and alignment (Indurkhya 1991a, 1992), we, nevertheless, maintain that conceptualization process also plays a crucial role in forming and understanding certain kind of analogies and metaphors—in fact, we would claim, most creative analogies and metaphor invariably involve reconceptualization, and do not result from matching and alignment of existing representations.

Of course, one could try to explain some characteristics of creative metaphors and analogies in terms of matching and alignment, as has been done in Gentner and Wolff (1994). However these explanations end up being needlessly convoluted, and generate some very unreasonable consequences. For instance, one explanation that is offered is that the new representation of the target is really a part of the old representation that is highlighted by the juxtaposition of the source and the target. But to account for the empirical evidence that parts of the after-the-metaphor representation of the target are not semantically related to the before-the-metaphor target, it is suggested that not all parts of the representation of any concept can be brought to mind at the same time, and an analogy or metaphor can focus attention on certain very low-salience part of the representation of the target that is normally not accessible; hence the similarities underlying the metaphor or analogy seems to created, even though they were there all along.

Obviously, we do not claim that this phenomenon of a metaphor highlighting low salience parts of the target never happens. However, to argue that all, or even most, of created similarities result from this phenomenon has the consequence that the semantic representation of any object or concept must be really huge, for it must include many potential representations and semantic features so that we can get the proper effect by highlighting an appropriate part of the representation when any possible source is chosen to describe the object. For computational modelling, this implies that in encoding the representation of the object, one must include every possible concept that can possibly apply to it—perhaps even compare the object to every other object in the domain to ensure that no potential similarities are unrepresented. And then these mammoth representations must be manipulated by the cognitive mechanisms of matching and alignment (or by their algorithmic manifestation in a computational setting). To keep and manipulate such enormous representations could easily prove to be cumbersome, unwieldy and grossly inefficient for any cognitive theory, or a computational model thereof.

On the other hand, incorporating the conceptualization process as a key cognitive mechanism in our framework has some advantages. For one thing, it allows one to keep smaller and more manageable representations of objects and concepts. Although mechanisms of matching and alignment can still operate on these representations, and can at times highlight their low-salient parts, the representations are themselves dynamic in that conceptualization process can be called into play at any time to create new representations from the SMD. These new representations can then again enter into matching and alignment process and so on.

Our approach also rescues perception from the back seat to which it has been relegated by most of the cognitive science and artificial intelligence research, where it is assumed that after perception has done its job and supplied the cognitive
apparatus with some appropriate representation, the ‘intelligent’ activities can begin. As has been convincingly argued for by Arnheim (1969) and Chalmers et al. (1992), much of the intelligence is embodied in perception itself, where crucial decisions are made as to what relations and structures are extracted from the stimuli, what is the focus of attention, and what concepts are projected on the stimuli to classify and organize it. To study cognition after perception is done is like searching for recipes for food that has already been cooked.

Finally, I would like to underscore the fact that cognitive modelling of similarity-creating metaphors need not await a complete understanding of similarity-based metaphors, as some might argue. Rather, given that the mechanisms underlying the two classes of metaphor are very different, the respective research on each class may proceed hand-in-hand. Moreover, since the crucial role played by similarity-creating metaphors in various aspects of cognition cannot be overemphasized, it is my firm belief that understanding the cognitive mechanisms behind similarity-creating metaphors can only dispel some of the mystery surrounding the creativity of the human mind.

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Notes
1. For instance, see the work of George Lakoff and his colleagues; especially Lakoff and Johnson (1980) and Lakoff and Turner (1989).
4. See, for instance, Black (1955), Mooij (1976), and Searle (1979).
5. I should caution here that the term ‘analogy’ is often used with many different senses (Indurkhya 1989), most of which are not synonymous with ‘similarity,’ although they make use of the concept of similarity in different ways. Here I am referring to usages such as in Gentner (1982).
6. As, for instance, in Gentner (1983) and Indurkhya (1986).
9. See Schön (1979) also.
13. See Kuhn (1962), Chapter VII; and also Kuhn (1957).
14. Of course, this process is not as abrupt and sudden as this sentence implies. There is invariably a period of adjustment where various attempts are made to stretch the existing paradigm to assimilate the anomalous data, and the new paradigm is subjected to a harsh criticism and various tests. See Kuhn (1962) for a detailed discussion of the process of adjustment to the new paradigm.
15. See also Turbayne (1962).
16. For a quick overall perspective of the gestalt psychology, see Köhler (1969).
17. See Kolars (1972), and Kolers and Green (1984).
18. Jean Piaget might have been the staunchest supporter of this thesis. Ernst Cassirer, following the Kantian doctrine that the external world is inaccessible and it is only our cognitive apparatus that differentiates it and gives it a ‘form’ in the process, however, diverged from Kant in recognizing that cognition is not based on a priori fixed principles, but is inherently developmental, capable of working in a variety of modes and creating a multitude of ‘worlds’ in the process: a theme that was later echoed by Nelson Goodman in Ways of Worldmaking.
20. See Lakoff (1987) for some recent arguments in support of this thesis.
21. For instance, Piaget himself uses ‘assimilation’ in at least two different ways: biological assimilation, a mechanism by which an organism absorbs energy from its environment and transforms it to a form...
that can be used by it, a familiar example being ingestion; and behaviour or cognitive assimilation, which is the process of reducing one’s sensory stimuli to some familiar concept, or network of concepts (cf. Vuyk 1981, Vol. I, pp. 65–67). Moreover, cognitive assimilation itself is given a broad scope: for instance, Piaget argues that it is primarily responsible for the formation of ‘memory’ (cf. Piaget 1976, p. 141).

22. This is a somewhat simplistic view, of course. To be more realistic, one would have to say that there are several mediating levels. For a discussion of the multi-level interaction between the concept networks and the SMD, see Indurkhya (1992), Chapter 5, Section 8.

23. Although I am talking here as if it is a two stage process—the grouping followed by the identification of groups with concepts—I would maintain that identification of the groups with the concepts is necessary for grouping the SMD. Or, in other words, the apparent two stages of the process are, in fact, one inseparable step.

24. See Piaget (1945), Part I, pp. 5–86, for a fascinating study of the role played by imitation in the early cognitive development of a child.

25. See also Goodman (1976), I. 2 (pp. 6–10).

26. The Q-morphisms of Holland and Quinn (1987, Chapter 2) provide another example of accommodation. In their model of cognition the environment is assumed to act on the subject via a set of feature detectors. These feature detectors group the SMD and establish a correspondence between the chunks of the SMD and the concepts of the subject. However, since the nature of the feature detectors is fixed, the grouping and the correspondence is predetermined. The subject can only modify the structure of her concept network to adapt.

27. See also Turbayne (1962), Chapter VIII, Section 4, for a very similar explanation of this phenomenon.

28. See Piaget (1945), Part II, pp. 87–212, for a detailed study of the role played by ‘play’ in the cognitive growth of children.

29. Of course, there may well exist intermediate cognitive layers between the concrete SMDs and highly abstract concept networks, as discussed in Indurkhya (1992, Chapter 5, Section 8).


31. See, for instance, Korf (1980); and also the account of ‘syntactic metaphor’ in Indurkhya (1991a, 1992).

32. Some earlier accounts of metaphor, notably those of Goodman (1976), Black (1977), Reddy (1979), and Lakoff and Johnson (1980), have also noted this point implicitly or informally.

33. See also Hesse (1974), pp. 48–51, for arguments leading to the conclusion that any classification necessarily results in a loss of verbalizable empirical information.

34. See also Turbayne (1962).

35. See, for instance, Q-morphisms of Holland and Quinn (1987).

36. This is formally captured by the first isomorphism theorem (Indurkhya 1991b), and its generalization in Indurkhya (1992, Chapter 6).

37. See Erman et al. (1980). In what follows, I will be idealizing Hearsay-II for the sake of my argument. The idealization, however, is not unreal. In fact speech understanding systems have matured quite a bit since Hearsay-II, and there is nothing in my arguments that attributes a ‘non-existing’ capability to a speech understanding system.

38. If this scenario seems a bit far-fetched to you, consider the humorous book Mots D’ Heures: Gousses Rames by Luis d’Antin Van Rooten. It contains meaningful text in French which, when read aloud, sounds like Mother Goose’s Nursery Rhymes.

39. This is consistent with the empirical research cited in Gerrig (1989).

40. It is also in this sense one can say that all knowledge is metaphorical (Indurkhya 1994a).

41. Although the key role played by change of representation in problem solving was recognized by AI researchers early on (Amarel 1968), it has received a more serious attention only in the last few years (Korf 1980, Lowry 1990, Subramanian 1990).

42. A notable exception is the Copycat system of Hofstadter and Mitchell (1991).

References


