# Metaphor and Information Flow

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**Abstract**

This paper develops a formal model for metaphor and analogy built on information flow theory, formal concept analysis and conceptual graphs. Metaphor and analogy are important principles of human cognition based on representational maps. The model suggested in this paper defines metaphoric use in terms of information transfer via an information channel with respect to contextual constraints.

## Introduction

The goal of this paper is to provide a formal model of the use of metaphors in information transfer or "information flow". Metaphors are a driving force for human cognition and for languages to represent novel concepts or situations. For example, many terms in computer technology are metaphorically used conventional terms, such as "file folder" and "desktop" (based on similarity in use) and "mouse" (based on similarity in shape and size). Metaphors usually do not just map single concepts onto single concepts but can transfer relations between abstract or real-world objects into an abstract, hypothetical world, such as digital "environments" with "cyber-networks", "connectivity", "information space" and so on.

Because of this mapping between representing and represented information, metaphors also present insights into the assumptions and possible conceptual structures that underlie the models or representations themselves. An understanding of the precise mechanism that metaphors employ can thus provide information on language understanding, processing and generation. Metaphors do not map all features and relations of a source domain into a target domain. In fact, frequently there is a reduction in detail as well as an aggregation of implicit or new structures.

The first section of this paper introduces the concept "metaphor" as found in the literature. It argues that metaphor is a prevailing principle that is fundamental to human cognition. The second section describes the frequent use of metaphor in the form of navigational representation. The third section discusses potential misuse of metaphors. The fourth describes representational aspects. The rest of the paper introduces a formal model for representing the information flow between the representing and represented parts of metaphors. The model in general, which builds upon Barwise & Seligman's (1997) Information Flow theory, Ganter & Wille's (1999) Formal Concept Analysis and Sowa's (1984) conceptual graphs, is introduced in the fifth section and applied to metaphor in the sixth section.

## Metaphor and Analogy

Metaphor and analogy (which are not discriminated in this paper) have been identified as important mechanisms of human cognition.

> And I cherish more than anything else the Analogies, my most trustworthy masters. They know all the secrets of Nature, and they ought to be least neglected in Geometry – Johannes Kepler

Marvin Minsky (Minsky, 1981), describes the ability to see one situation in terms of another, which is utilized in knowledge transfer, as follows :

> analogies – along with the knowledge of how to apply them – are among our most powerful tools of thought. They explain our ability sometimes to see one thing – or idea – as though it were another, and thus to apply knowledge and experience gathered in one domain to solve problems in another. It is thus that we transfer knowledge via the paradigms of Science. We learn to see gases and fluids as particles, particles as waves, and waves as envelopes of growing spheres.

Lakoff & Johnson (1980) view metaphor as not just an occasional tool, but as conceptually pervasive:

> ...metaphor is typically viewed as characteristic of language alone. ...on the contrary, metaphor is pervasive in everyday life, not just in language but in thought and action. Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature... Our concepts structure what we perceive, how we get around in the world, and how we relate to other people. Our conceptual system thus plays a central role in defining our everyday realities. ...the way we think, what we experience, and what we do every day is very much a matter of metaphor. (p. 3)

Hofstadter (1999) concurs:

> One should not think of analogy as a special variety of reasoning...analogy is everything, or very nearly so, in my view.

He suggests that every concept we have is a tightly packaged bundle of analogies, and when we think, we move fluidly from concept to concept – from analogy-bundle to analogy-bundle – via analogical connections. In this light, metaphors may be seen as a natural extension of the organizing principle of human cognition.

Metaphors have entailments through which they highlight and make coherent certain aspects of our experience (Lakoff & Johnson, 1980, p.156). They are grounded in correlations with our experience as navigators in a spatial world. This leads naturally to metaphors that provide cues for orientation and navigation.

## Navigation as Metaphor

Navigation is essential to animals and humans. We fix on a target or object at a distance and navigate to it, taking the most direct or economic route and avoiding obstacles. Navigation in space may be fundamental to intelligence. Llinas (1987) points out that the development of a nervous system is a property of actively moving organisms, that there exist organisms that appear as plants in one stage of life while in another stage of life swim freely, and that in the former stage they have no nervous system, while in the latter they

> possess a brain-like ganglion which can be informed about the environment by peripheral sensory input... [which has] the necessary connections to deal with the continuously changing environment. (p. 341)

Navigation is so important in human conceptual processing that it is difficult to define a boundary between the use of actual navigational terms and the metaphoric use of navigational terms. It is also bound inextricably to the spatial substrate it navigates – whether physical or metaphoric. Navigation, similar to many of Lakoff & Johnson's LIFE metaphors, involves a journey (as in, LIFE IS A JOURNEY, TIME IS A JOURNEY, AN ARGUMENT IS A JOURNEY, and A JOURNEY DEFINES A PATH). Few journeys or paths are taken in a straight line. They involve overcoming or avoiding obstacles in order to arrive at the destination – this is why we need and employ maps. Map metaphors take consideration of the shape of the land, or landscape, where the action is expected to occur. This always involves identifying features or landmarks to provide orientation as the landscape changes. In this way a landscape is both a substrate and a container which forms the boundaries within which the landmarks or features are found.

Lakoff & Johnson have noted this phenomenon of interacting metaphors and use the term "coherence" to describe the overlap between the entailments of differing metaphors. For the ARGUMENT IS A JOURNEY metaphor ("get to the point") they compare the ARGUMENT IS A CONTAINER metaphor ("that argument doesn't hold much water;" "the *core* or *heart* of an argument") and show that they may be used together – "At this *point* our argument doesn't have much *content*" (Lakoff & Johnson, p. 92). They distinguish the form of an argument from the content of an argument and show that a journey is a path and a path has a surface, as does a container – more content corresponds to more surface, which is applicable to both metaphors. They extend this to an ARGUMENT IS A BUILDING metaphor ("this argument has a firm foundation and a strong framework") and demonstrate that all three cohere – "*So far* we have *constructed* the *core* of our argument" (Lakoff & Johnson, p. 102). So, metaphors affect the daily activity of finding our way in our conceptual worlds, facilitating transitions from topic to topic – or from context to context – in coherent ways.

## Caveats of Metaphor Use

It is a maxim that "we see what we expect to see." Conversely we are sometimes blind to possibilities that do not match our current paradigm. Metaphors and paradigms simplify our reality – they are models we can manipulate and measure against. We use them to predict outcomes. But they can mislead us into false conclusions. Ackerman (1996) warns against possible negative consequences of using, accepting, or basing policy on metaphors, uncritically. He defines two classes of metaphors which may cause problems. The first may hide the real restrictions of a technology by claiming attributes of human or social phenomena. An example is "virtual community" which in its use may ignore facets of democracy, education, community, equality and other important features of our society. The other class of metaphors,

> typified by a specific use of "digital library", restricts the social or human phenomena to only that which is possible through technology or even specific technologies. Metaphors like "virtual community" and "information highway" summon great explanatory power. These metaphors not only provide explanatory power, they also provide avenues for distortion and misrepresentation. ...we must weigh any explanatory power against the potential error.

Ackerman believes that such metaphors, because they are misleading, bring false hopes and idealism regarding digital technologies. Metaphors bring with them connotations which may not apply to the new domain – they are always limited in some way and the limitations must be defined if they are not to mislead. Lakoff & Johnson put it this way:

> Metaphors may create realities for us, especially social realities. Metaphor may thus be a guide for future action. Such actions will, of course, fit the metaphor. This will, in turn, reinforce the power of the metaphor to make experience coherent. In this sense metaphors can be self-fulfilling prophecies.

A detailed understanding of what metaphors are and how they are employed in natural language can thus provide guidelines, for example, for advertisers to use metaphors as persuasive figures of speech but also to help consumers to detect the misuse of metaphors.

## Metaphors as Representational Maps

In all of the models for metaphor described above the common thread is a representational aspect.

> The function of a representing world is to preserve information about the represented world. (Palmer, 1978)

Metaphors involve a representation of a set of objects with some relation defined or assumed between them that is mapped to a different set of objects in a different context. Gentner & Forbus (1991) describe this as a mapping from one situation to another which is governed by the constraints of structural consistency and one-to-one mapping. As will be described below, while we agree with the condition of "structural consistency", in our model metaphors are not just simple mappings from a source to a target domain but instead require the establishment of a shared channel that depends both on source and target before the metaphor can be "mapped" from source to target.

In the absence of a real-world coordinate system a framework needs to be generated to give context or contain the information objects in an information space or map. There should also be some systematic method of mapping the information objects into the information map from their source. For example, a geographic map represents real-world geographic features (the original objects) as icons or colored areas on a paper map. The definition also includes "with some relation defined or assumed between" the first set of objects, where the relation holds in both contexts. For a geographic map this implies a scale which preserves relative distance between the objects (or for a topographical map, preserves the relation of relative elevation, density or direction) – for example miles in the real world are represented by inches in the map.

Palmer (1978) calls mapped relations, where the corresponding functional order of the features is retained, "operationally defined relations." An example is color ramping, which produces the effect seen in maps where white indicates mountain tops; brown, hills; green, plains; and on down through shades of blue to indicate various depths below sea level. The relation of distance between cities is a binary relation, while the relation of population, is a unary relation. Palmer calls unary relations "properties," and they are what we refer to as "features." Binary relations generally define the substrate of a map, while unary relations define the information associated with the objects found on the map. Both types of relations can be part of metaphoric representation. The following formal model focuses on binary relations but can be extended to n-ary relations in general.

## A Formal Model of Information Flow

The formal model of metaphor described in this paper extends Barwise & Seligman's (1997) information flow model by incorporating relational structures and an explicit representation of context. Barwise & Seligman's model describes information flow as *infomorphisms* between classifications. Formally, a classification $(A, B, R)$ consists of a set $A$ of *tokens*, a set $B$ of *types* and a relation $R$ between tokens and types (i.e., $R \subseteq A \times B$). For example, tokens can be objects and types can be words or attributes describing the objects. This definition is equivalent to a formal context in formal concept analysis (Ganter & Wille, 1999). Therefore a concept lattice can be constructed from a classification in the following manner. Let $R(A)$ denote the set of tokens that all objects in $A$ share and, vice versa, $R(B)$ denote the set of types that all tokens in $B$ share. A concept is then defined as a pair $(A_1, B_1)$ with $A_1 \subseteq A$, $B_1 \subseteq B$ and $R(A_1) = B_1$ and $R(B_1) = A_1$. A concept lattice is the set of concepts of a formal context (or classification) ordered by a subconcept-superconcept relation defined as $(A_1, B_1) \leq (A_2, B_2) :\Longleftrightarrow A_1 \subseteq A_2$ (or equivalently $B_2 \subseteq B_1$.)

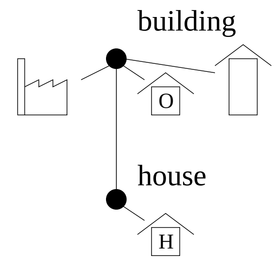


Figure 1: Lattice for house/building

Figure 1 shows a simple concept lattice of a classification. The tokens are prototypical representations of different kinds of buildings, such as (from the left under "building") a factory building, a small office building, an apartment building and (under "house") a small residential building or house. The types are the English words "building" and "house". The concept for "house" is a subconcept of the concept for "building" because all houses are buildings. So to list all "building" tokens, the union of the tokens directly under "building" and of the tokens directly under "house" and thus indirectly under "building" is formed.

While concept lattices describe the relations within one classification, Barwise & Seligman's infomorphisms can be used to describe the information flow between different classifications. An infomorphism is defined as a pair $(f, f')$ of mappings between two classifications, $(A_1, B_1, R_1)$ and $(A_2, B_2, R_2)$, such that for all tokens $a$ of $A_1$ and for all types $b$ of $B_2$: $f(a)R_2b \Longleftrightarrow aR_1f'(b)$. The two classifications are thus not completely dual to each other because the tokens are mapped from the first one into the second one, whereas the types are mapped from the second one into the first one. The first one, whose tokens are mapped, (in this case $(A_1, B_1, R_1)$) is called a *channel*.

An information flow channel is itself a classification that contains some types and tokens from the other classifications. The Barwise & Seligman model thus extend older Shannon-Weaver type models of information transmission. In older models a channel is usually a passive message conducting cable, such as a wire between computers or air which transmits human utterances. The encoding and decoding of the messages is achieved at either end of the channel. In Barwise & Seligman's model the channel itself participates in the translation process between sender and receiver. It is not just a physical cable but in some sense a "conceptual cable" between the two ends. The advantage is that the translation process itself can be separately analyzed and represented.

As the example in Figure 2 demonstrates, information flow theory can be used to describe how the English words "house" and "building" can be translated into German. The

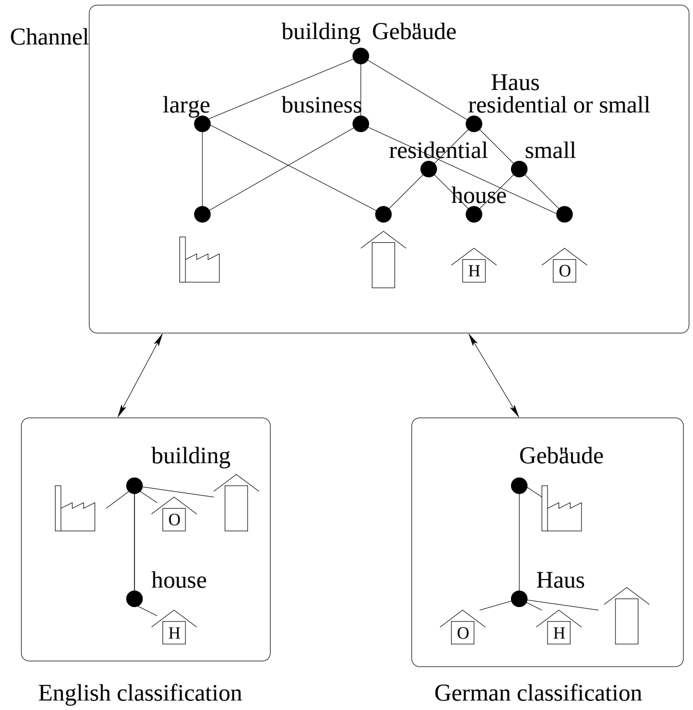


Figure 2: An information channel translating between house/building and Haus/Gebäude

German words "Haus" and "Gebäude" are not completely equivalent to "house" and "building" because in German office buildings and apartment buildings can be called "Haus". To translate between English and German, separate classifications are constructed for English and German words, which are then translated via a channel, which is the large box in Figure 2.

In this case the channel and the external classifications each have the same set of tokens. The set of types in the channel contains the sets of types from the external classifications. The other types in the channel are attributes that could be derived from dictionary definitions of the words in each language. The mappings $f, f'$ are both identity mappings. The channel shows that German "Haus" is more general than English "house". English "house" is always translated (at least with respect to this example) as "Haus" because the concept for "house" is a subconcept of "Haus". German "Gebäude" is always translated as "building" because the set of concepts that are "Gebäude" but not "Haus" is a subset of the concepts for "building" but not "house". English "building" can always be translated as "Gebäude" but if it refers to "apartment building" or "office building", "Haus" is more appropriate.

The information flow model thus provides an explanation for changes in information content during a message transmission. Infomorphisms between classifications preserve some information while facilitating flexibility in the information flow. In language applications, if tokens represent objects and types are words of a language, the classifications provide different ways of verbally expressing statements about a shared set of objects in the channel. The different classifications can be expressed in different languages or can be different viewpoints expressed in a single language.

Several classifications can be connected via infomorphisms into a shared channel. But they can also connect to different channels thus forming a network of classifications and channels. Such a network can be used to express Lakoff & Johnson's notion of "coherence" of metaphors as mentioned above. It should be remarked that while Barwise & Seligman's model has some obvious appeal for explaining phenomena known from information and communication theory, it is a formal model. Neither the original model nor the application to metaphor presented in this paper make any claims as to whether the formal model corresponds to actual cognitive processes. The purpose of this model is to potentially support machine-aided information processing.

An important component in information flow is "context". Each classification provides a context for its tokens and types. Statements about them hold only with respect to each context. For example a statement, such as "house can always be translated as Haus", may not be correct with respect to other contexts than the ones given in Figure 2. On the other hand, the example shows that to translate or disambiguate a few words, such as "house" and "building", fairly small contexts are sufficient. It is not necessary to construct a complex (or complete) picture of relationships among words in each language. Instead the words of a language can be represented in a network of small contexts connected via infomorphisms and channels.

## A Formal Model of Metaphor

Classifications form conceptual hierarchies of concepts (or concept lattices). Not all relations in language are primarily hierarchical. Verbs, for example, constitute n-ary relations among the parts of a sentence. These relations, which are not usually hierarchical but often used in metaphors, can be represented as semantic networks or conceptual graphs (Sowa, 1984). Figure 3 shows an example of a conceptual graph of the sentence "the farmer ploughs the field". To describe complex linguistic or conceptual phenomena such as metaphor, Barwise & Seligman's theory thus needs to be extended to include general relational structures or conceptual graphs. We suggest the following definition: a *relational infomorphism* is defined as a pair $(f, f')$ of mappings between two classifications, $(A_1, B_1, R_1)$ and $(A_2, B_2, R_2)$, which have further relations $R_{11}, R_{12}, \ldots \subseteq A_1 \times B_1$ and $R_{21}, R_{22}, \ldots \subseteq A_2 \times B_2$, such that for elements $b_1, b_2 \in B_2$ and for each pair of corresponding relations $(R_{1i}, R_{2i})$: $b_1 R_{2i} b_2 \Longleftrightarrow f'(b_1) R_{1i} f'(b_2)$.

An example of a metaphoric use of "plough" as in "the farmer ploughs the field" is "the ship ploughs the sea". In this case, the first sentence presents a default context for "plough" that people usually associate with "plough". Using the formal model developed so far, we suggest that this metaphor is not just a simple mapping from "farmer" and "field" onto "ship" and "sea" because in that case it would be difficult to identify the specific conditions that allow for such

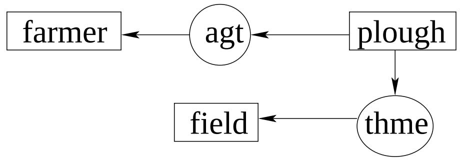


Figure 3: A conceptual graph

a mapping. Instead, we suggest that there is something in common between the contexts of ships sailing the sea and of farmers ploughing fields that facilitates the metaphoric use. It appears that the commonality or channel between both contexts involves "a forward moving object with a leading edge ploughing an object that can be parted." This channel is generated based on both individual contexts because, for example, the context of "a ploughing farmer" by itself does not necessarily emphasize the existence of "a leading edge". In fact, in this example, "farmer" is used metonymically for the "farmer's plough". The "plough"-metaphor therefore depends on implicit features of "farmer". The metaphor is established by using a "channel" in the sense of the information flow model and a relational infomorphism that transmits the relation (in this case "plough") across the channel.

Figure 4 shows a schematic view of the example. Infomorphisms establish a mapping of "farmer"/"field" and "ship"/"sea" onto the corresponding concepts in the channel. These mappings are not simply instantiations of the abstract concepts in the channel because, for example, a farmer is not a "forward moving object with a leading edge" but instead a "forward moving object which uses an object with a leading edge". These details need not be explicated but are contained in the infomorphism. The infomorphisms are further relational infomorphisms because the "plough"-relations of the individual classifications are mapped. For the "plough"-relation there is a directionality from the farming context into the channel into the sailing context. The concept of "ploughing" cannot be expressed using only native sailing vocabulary. The metaphor thus adds a new concept to the sailing vocabulary. In summary, the "plough"-relation is mapped from the farming context into the sailing context but this mapping depends on the prior establishment of a channel.

Defining metaphor as a channel with relational infomorphisms is necessary but not sufficient. There have to be some additional structural consistency constraints (Gentner & Forbus, 1991) about what constitutes a context. For example, the sentence "the ship ploughs the rose-bed" would not usually be considered a metaphor of "the farmer ploughs the field" even though a channel and relational infomorphisms could be constructed because there may be no sensible context for that sentence. The definition of a classification (or formal context) as presented above is necessary but not sufficient because it is a formal definition in terms of tokens and types which does not consider semantic relations or common sense knowledge. In general, it is difficult to define what a context is. There are some established theories for modeling contexts such as situation theory (Devlin, 1991) which can

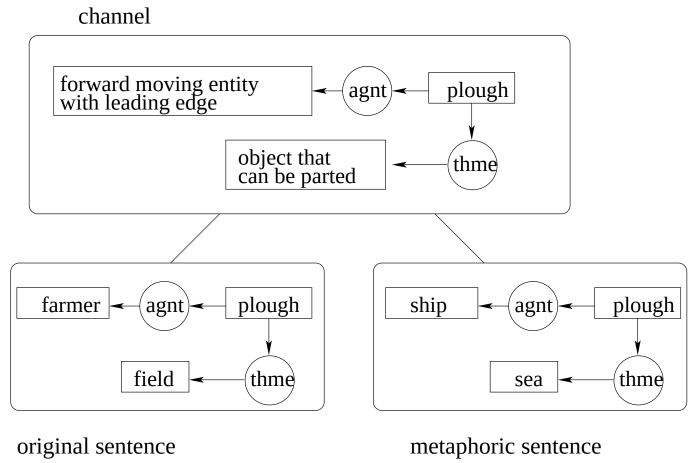


Figure 4: A metaphor

be employed. For this paper it is sufficient to say, that apart from channel and relational infomorphisms, an explicit representation of "context" is the third necessary component of a model for metaphor.

The classifications involved in metaphoric use must observe contextual consistency constraints and a mapping among contexts. In summary, *metaphoric use* can be defined as *a set of two classifications, a source classification and a target classification, such that a channel with relational infomorphisms can be established between them according to which the (metaphoric) relation is mapped from the source to the target classification and all involved classifications observe contextual consistency constraints*.

## Conclusion

This paper analyses some aspects of metaphors or analogies, which are basic to conceptual processing, frequently based on navigation and involve representational maps. A detailed understanding of metaphors can aid in the processing, understanding and generation of information. It can also provide insights into culturally influenced conceptual organization. The formal model developed in this paper claims that metaphors are not just one-directional maps but consist of relational infomorphisms transmitted via information channels, which are built from the contexts involved in the metaphors, with respect to consistency constraints provided by the contexts.

Future research will involve a closer analysis of Lakoff & Johnson's coherence among metaphors, which in our model corresponds to a network of channels and infomorphisms. Furthermore, the applicability of the model to a wider range of linguistic phenomena could be investigated.

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