Generics and Metaphors Unified under a Four-Layer Semantic Theory of Concepts

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Acknowledgment: The naming order of authors is alphabetic. The work presented is thoroughly cooperative. A preliminary version of this paper was read at The Third Conference on Experience and Truth, Taipei, Taiwan, 24-25 November 2006 and published in the proceedings of the conference (Soochow University, Taipei, Taiwan). Authors give their thanks to those present at the conference for valuable questions and helpful suggestions. Biographies are located at the end of this paper.

Abstract. In this paper, we intend to establish a unified semantics to interpret generics and metaphors. We argue that they have much in common beyond their apparent differences, and that there is no firm line separating the two. This work is carried out in a four-layer semantic structure for concepts. Each layer matches up with semantic entities of a certain type in Montague's intensional semantics. We argue that a linguistic term denotes a concept and a sense, which are functions. For any given context, the concept denoted by the term specifies its intensions and the sense of the term determines its extensions. Intensions are viewed as sets of senses. In this picture, a concept is no longer traditionally viewed as a container with fixed meanings in it. Rather, a concept is alive and active, dynamic and distributed. Meanings are constructed with respect to different input contexts. Generics extend the intension of the concept expressed by the subject term with the sense of the predicate term. Metaphors transfer part of intension of the vehicle concepts from the established domain to a new domain where the topic concept applies. The results we gain about the semantic interpretation of concepts simultaneously account for generics and metaphors. This proposition unifies logic and rhetoric, separated by Greek philosophy more than 2000 years ago.

1. Motivation

Both generic and metaphoric expressions are ubiquitous in our languages. Our knowledge about the world builds mostly on generics like "Birds fly" and "Potatoes contain Vitamin C." Human communication relies heavily on metaphors like "Time is money" and "Argument is battle." Much research has been devoted to them respectively, but few common features have been explored between these two pervasive linguistic phenomena. It sounds startling that semantic interpretation of generics and metaphors shares the same framework. This is yet the view that this paper pursues to establish.

We start with some examples to demonstrate that generics and metaphors are not isolated from each other, but are instead closely related in natural language.

(1a) The sun is bright.
(1b) Einstein is bright.
(1c) Einstein brightened modern physics.

There is no doubt that (1a) is a generic sentence. (1b) is normally considered a metaphorical sentence, but this may be controversial. Some people may argue that smartness is part of the meaning of "bright", just like the shining aspect of brightness is. Thus for them, "Einstein is bright" is also a generic statement. It is more apparent that (1c) is a metaphor, as physics is not a material object and cannot be physically brightened. It seems that generics and metaphors are two ends of a spectrum. While (1a) is a generic sentence, (1c) is quite metaphorical. In between them, there are sentences like (1b). In contrast to the brightness of the sun, professors being bright is metaphorical. On the other hand, the sentence (1b) is also generic and it sets the basis for the further metaphor expressed in (1c).

It becomes interesting when a generic sentence like (1a) is put adjacently to a metaphorical sentence like (1b). Apparently, they bear the same syntactic structure. Do they have a similar semantic interpretation? They could share the coarse-grained extensional semantics in which the unary predicate "bright" is interpreted as a class of bright objects and both sun and Einstein are members of this class. However, it has been well established that an extensional interpretation for generics is not right. It has no way to account for exceptional situations where, say, in a cloudy day or a misty day, the sun is not bright. In addition, an extensional interpretation for metaphors like (1b) does not work, either. It is wrong to count Einstein as bright in virtue of his being a bright object in the same way the Sun is, simply because he is not such an object. Then, the question becomes this: is there any other semantics that could possibly serve as a common ground in interpreting both generics and metaphors? This question deserves an answer, as examples like (1) are pervasive in our daily language when we begin to pay a little attention to them. Here is another one.

(2a) Birds fly.
(2b) Airplanes fly.
(2c) Nowadays people fly worldwide.

(2a) is an exemplary generic sentence. It is common sense that people cannot fly like birds. However, nobody seems to care about correcting the seemingly categorical mistake in (2c). That is because (2c) is naturally understood as a metaphorical statement, not as literary true. "People fly" is true not in the sense that they fly with their wings but in the sense that they fly by taking flying vehicles such as airplanes.

The demonstrated syntactic similarity between generics and metaphors is not at all limited to atomic sentences. It is also fairly easy to find such pairs of sentences with a relational predicate like "bite" in example (3).

(3a) Dogs bite postmen.
(3b) Inflation bites retirement savings.

Sometimes, the generic meaning and metaphorical meaning can even be conveyed by the same sentence for different contexts. A Chinese proverb, whose translation in English is something like (4) below, illustrates this phenomenon.

(4) Real gold shines everywhere.

(4) has two readings: a generic one and a metaphorical one. The generic reading literally states that being shining is a property intrinsic to being real gold. A piece of real gold may be buried deeply under ground, or covered by dust. As long as it is a piece of real gold, it shines wherever it is fortunately or unfortunately located. In the context where a physical characteristic of real gold is concerned, (4) describes shine as a generic property of real gold. However, most of times when (4) is uttered, its metaphorical meaning is actually intended. (4) could metaphorically mean that some gifted person always shows talent regardless of the working environment. In the context where a friend is badly treated and has to leave his company, (4) can be said to comfort the friend that his talent will be recognized in any area that he will be involved in. In both contexts, (4) is a true statement, generically or metaphorically.

The linguistic phenomenon of fusing generic and metaphorical meanings in one sentence has a scaled down version and a scaled up version. The scaled down version goes to terms. Some terms apply to different domains where their meanings metaphorically mirror their original meaning. The term “virus” is such an example. The word “virus” initially refers to biological viruses that invade biological bodies, replicate themselves rapidly and cause body sickness. In modern time, the word “virus” also applies to the domain of computers. A computer virus is a piece of malicious software that spreads out quickly among computers and harms the systems that run it. Computer viruses, though not alive, share many of characteristics of biological virus, and hence the metaphor stands.

The scaled up version of the co-existence of generic and metaphoric readings can be observed at the discourse level. Ancient Chinese poets are very good at purposefully using the coexistence of two readings in poetry. Juyi Bai in Tang Dynasty wrote in *Grass*, one of the most well-known poems:

The grass is spreading out across the plain.

Each year it dies, then flourishes again.

It's burnt but not destroyed by prairie fires,

When spring winds blow they bring it back to life.

More than too often this poem has been recited to describe something that has strong vitality like grass and whose existence is not suppressed by external force.

It is hard to believe that the striking similarities between generics and metaphors are merely due to accident. We tend to think that they are not separable from each other. The generic meaning sets up a foundation upon which metaphorical meanings from various angles can be derived. If a developed metaphorical meaning gets widely accepted it becomes part of the generic meaning.

In the rest of paper, our analysis starts from the semantic interpretation of terms. The dual meanings (or even multiple meanings in many domains) of a term are to be explained by the four-layer semantic structure of the concept that the term expresses. The semantics of concept serves as a common ground, on which a uniformed semantic interpretation for both generic and metaphorical sentences will be established. Metaphorical discourses are out of the scope of this paper and need to be discussed in further work.

2. Four Semantic Layers of Concepts

There has been a long tradition of dividing the use of a term into its extensional meaning and intensional meaning ([10]). This bipartition is also discussed in other vocabulary like sense and reference ([9]), and concept and object. It has been commonly agreed that the extension of a term like a common noun is meant to be a number of individuals that the term may predicate, while the intension of a term signifies a group of attributes. Objects that fall in the extension of a term possess attributes contained in the intension of the term. The words “intension”, “sense” and “concept” are used interchangeably, as opposed to objects that they denote.

Such a traditional view is oversimplified in understanding a concept. It falls short on many grounds. First, a generic attribute like the flying of a bird is in a tangled relationship with the concept of bird. Flying is not a necessary condition for being birds. Penguins do not fly but they are still classified as birds. If flying is one of the attributes contained in the intension of the term “bird”, then the extension of “bird” is smaller than what we have actually accepted. According to this narrowed extension of “bird”, penguins should not be called “birds”. If flying is not included in the group of characterizing attributes of birds, then two questions are left unanswered: (1) What is the relation between the flying capability and being birds; and (2) In virtue of what “birds fly” is a true statement.

Second, the bipartition of extension and intension leaves no room for metaphors. With this traditional view, if extensions are different, then the intensions and hence the concept that determine them must be different. In case of “virus”, the terms “biological virus” and “computer virus” have disjoint extensions. They denote two different concepts that may be marked as b-virus and c-virus. Such an understanding shows little of the metaphorical flavor of applying the concept of virus originated in the biological domain to the computer domain, which is against our intuition. This view suggests that a new word is better coined to denote the new concept constructed from applying an existing concept to a new domain. If one and the same word is used in two different domains, then it is virtually two words that coincidentally have the same appearance. A word with multiple meanings in different areas could have been split into multiple words. For example, the word “bed” refers to a piece of furniture, as well as the bottom of a river. The bipartition view suggests that two separate uses of “bed” could be differentiated as “bed1” and “bed2”. Each of them has its own intension and extension. They denote two different concepts. Again, this view has no way to explain the metaphorical link between one usage and another usage of the same word. Even in situations where a new word is indeed coined, there may still be a clear metaphorical trace from the original concept to the new one. For example, “phishing” denotes the method of trapping users into submitting their personal information to fake websites, which is a metaphor of the fishing activity. The traditional view of concept can hardly capture the metaphor between “fishing” and “phishing,” nor can it explain the choice of “phishing” for the malicious activity rather than anything else, say, “claphing.”

Third, the traditional view of concept can by no means account for the link between generics and metaphors. This is a corollary of the first two defects that have been discussed. Since the traditional view of concept cannot even account for generics or metaphors as stand-alone linguistic phenomena, it could not possibly provide a story to link these two.

Having observed the problems with the traditional understanding of concepts, Zhou and Mao ([20]) have proposed a new semantic theory of concepts. They have argued that concept, intension, sense, and extension are all different notions and are related to each other as follows: (a) Concept determines intensions; (b) An intension is a set of senses; (c) Sense determines extensions. Concept, intension, sense, and extension together consist of four semantic layers of a linguistic term. In order to show how this four-layer structure works nicely as a platform upon which things like generics, metaphors and concepts start fitting together, we elaborate each layer a little bit in the following sub-sections.

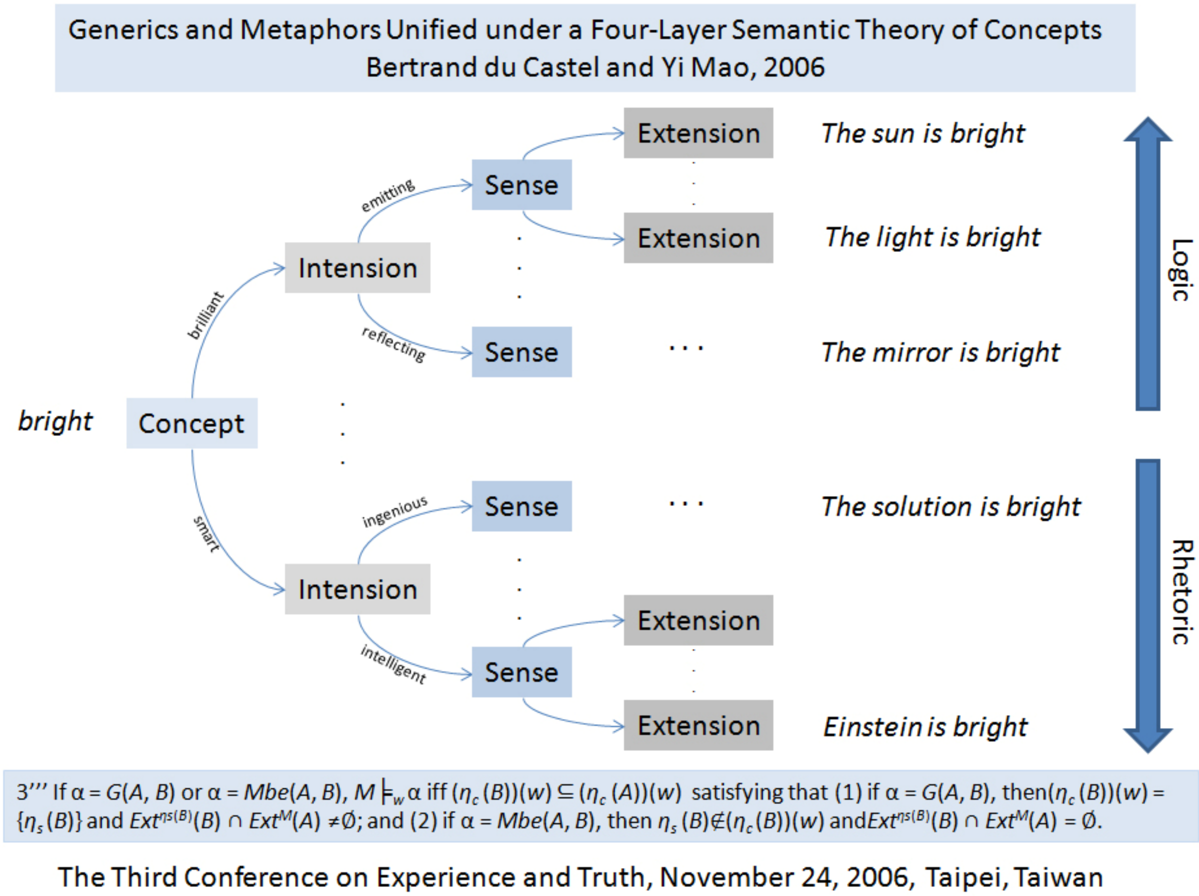

Figure 1 (2011): "Bright" in the four-layer semantic theory of concepts

2.1 Formation of Concepts

Traditionally, concepts are abstraction of the things in their extension. They omit the differences of individual entities and apply equally to every thing in their extension. Linguistic terms are used to label concepts. Many different terms in different languages may designate the same concept.

According to Locke ([13]), a general idea (i.e., a concept) is created by abstracting the common characteristics from several particular ideas (i.e., individuals). The abstract general idea or concept that is signified by the word "dog" is the collection of those characteristics that are common to individual dogs like Fido, Spot and Amber.

Kant has investigated the generation of empirical *a posteriori* concepts and summoned that they are created in three logical operations ([11]): comparison, reflection, and abstraction. In order to make our mental images of individual objects into concepts, one must be able to compare them to one another, reflect over how they can be comprehended in one consciousness, and abstract away everything else by which they differ.

Under the traditional view of concepts, we have to accept the consequence that several partly or fully distinct concepts sometimes share the same term in our language. For example, the term "close" is shared by several distinct concepts in the spatial domain, in the temporal domain, and in the domain of human relationships. However, the relationship between different concepts of close that are expressed by the same linguistic term "close" is left unexplained and indeed cannot be explained.

Cognitive Linguistics ([6], [7], [19]) makes a significant contribution by linking some concepts through structural mapping. In contrast to the traditional view that concepts in different domains are irrelevant, this theory advocates the notion of transformation that derives abstract concepts from concrete concepts that are gained from embodied experience. In the example of the term "close", it first of all expresses the concept that is gained from the spatial domain. Later on the meaning of the term "close" is extended to cover more abstract concepts of being close in temporal domain and even in the domain of human relationships.

We applaud the important step that Cognitive Linguistics takes to connect concepts from different domains. However, the understanding of concepts is still under the traditional framework. Although concepts from different domain now may be associated via transformations, they are still distinct concepts. We propose that a term like "close" has different senses in different domains, but it denotes one and the same concept that consists of senses in many different domains. We do not consider concepts as synonyms of senses. While senses take the role of the traditional understanding of concepts, our new understanding of concepts is built upon senses. The extended layers in comprehending concepts make room to account for generics, metaphors, and the relationship between them. The layered structure to form concepts can be observed in the language learning process of children.

2.1.1 Categorization: from Extension to Sense

In contrast to the traditional view of concepts, we think the categorization step to group things together under the same term in any given circumstance is to form a sense of that term. Mathematically speaking, the sense of a term is a function that determines the denotations of a term in all contexts. When a baby starts learning a new word like "dog", it is the sense of "dog" as a function of denotations ranging over contexts that she tries to comprehend. She tentatively attaches the word "dog" to some objects in her surroundings. She will either be praised or corrected depending on whether her use of the word "dog" is in accord with adults' use of this same word. It is very likely that she goes through a stage where she is able to properly use a word in some contexts, but not all of them. For example, she knows that her Mom's pet Fido is a dog, but she does not know that her neighbor's furry Snowball is also a dog. At that moment, the sense of the word "dog" that she grasps is merely a partial function. A baby can quickly expands the senses of words from partial functions to full ones and use words in exactly the same way that the community requires for her to successfully communicate with others.

We think that the focus of language acquisition is to gain the capability of properly applying words to the intended objects in any contexts. It focuses on the categorizing and labeling functionalities of linguistic expressions. Although categorization depends on certain common characteristics shared by individual objects, it is only required to the extent of extensions that can be determined. Young children are able to correctly use words for identifying objects without fully understanding their common properties. For example, a two-year-old Luisa can tell you that she has seen whales at Sea World without knowing that whales are mammals, which is an epistemic issue she may learn later in life.

Putnam criticized the traditional approach of analyzing a term via a set of properties shared by objects that the term denotes ([18]). He claimed that this approach did not work because of abnormal objects and discoveries of new properties. Using Putnam's example, a blue lemon is still called a lemon even though lemons are supposed to be yellow. The problem pinpointed by Putnam stems from the confusion of sense and intension, which we will discuss shortly. Our view is that the sense of a term does not have to cover all actual and potential properties that are normally associated to the term. We deliberately make the sole task of senses to be identifying denotations. The fact that children at their early age can correctly use the general names without having knowledge about all properties of objects called under those names confirms that determining factors of denotation of a term are divergent from a set of shared properties.

2.1.2 Generalization: from Sense to Intension

As we define the sense of a term to be a function that determines the extensions of the term in any context, it is only relevant to a set of core facts that are crucial in identifying denotations. Then a question can naturally be asked: what is the relationship between a term and all of its associated properties? Our answer to this question is that the intension of a term is a set of senses that covers all associated properties of this term.

While the sense of a term is solely responsible for determining the extensions of the term in all contexts, the intension of the term, as a set of senses, is not directly tied up to the extensions of the term. After a child has learnt how to correctly use a word, she has grasped the sense of this word. What can or cannot be referred by this word in a given context is relatively fixed and stable from that point on. However, the intension of the word can be much more enriched during a later learning process. The enrichment of the intension is a matter of knowledge acquisition. Much of world knowledge is stated in generic sentences as in (5a)-(5e) below.

(5a) Birds fly.
(5b) Birds lay eggs.
(5c) Birds have feather.
(5d) Birds build nests.
(5e) Birds eat grain.

Generic sentences are not about denotations, but about intensions, of terms that constitute generics. This view has been argued for by scholars like Pelletier and Asher ([17]), and conclusively supported by the exception tolerance feature of generics. We second this position.

In connection with the distinction between sense and intension that we proposed, we start to see that generic sentences of the form *SP* specify the membership relation between the intension of the subject term *S* and the sense of its predicate term *P*. Generic sentences in example (5) specify that the intension of the word "bird" contains flying, laying eggs, having feather, building nests and eating grain. Generics make assertions that the sense of the predicate term is a member of the subject's intension. For instance, according to (5b), the sense of "laying eggs" is included in the intension of the term "bird". The intension of a term is enriched or specified via generic statements.

In the process of knowledge acquisition, generic sentences express the knowledge that the sense of the predicate term should be added to the intension of the subject term. This piece of knowledge will later be recorded and carried on in the enriched intension of the subject term. In the process of knowledge transfer, a generic sentence shows that the intension of the subject term contains the sense of the predicate term. For instance, by understanding the meaning of generic sentence (5a), one can gain the knowledge that birds in general fly. (5a) is not a statement that describes a common property that every bird has. Some birds like penguins do not fly, while (5a) is widely accepted as a true statement.

2.1.3 Metaphors: from Intension to Concept

We not only differentiate intension from sense, but also differentiate concept from intension. Like senses, concepts are functions parameterized by contexts. As opposed to senses, concepts take intensions as their values. The characteristic of concept as a function becomes apparent in multiple contexts where metaphorical expressions are found in use.

Lakoff and Johnson ([12]) have showed us that we heavily use metaphors like "Time is money" and "Argument is war" in natural language. Metaphors can express abstract ideas that we cannot easily express using literal language as in "Love is a journey." Metaphors allow the communication of complex configurations of information in a succinct manner to capture the similar structure of a well-understood entity. For instance, "A cell is a factory." The use of literal language to communicate the same meaning would not be cumbersome and inefficient but rather impossible.

While new metaphors are created everyday in poetic, political, religious, and scientific writings, some old metaphorical expressions "freeze" their metaphorical meaning as part of their literal meaning via frequent usage. This phenomenon is known as the death of metaphor. For instance, people rarely realize that the expression "is close to" in "Thanksgiving is close to Christmas" is a frozen spatial metaphor for time. However, as time "goes by", the term "close to" nowadays applies equally well to the domain of time as it does to the domain of space, and so does it apply to the domain of human relationships. The applied meanings of the term "close to" in various domains together have built up the concept that "close to" expresses.

The phenomenon of polysemy demonstrates that words often not only have meanings in one domain but also have systematically related meanings in other domains. Lakoff and Johnson ([12]) have given us a dozen of such examples other than "close to": up, down, rise, fall, high, low, hit bottom, and so on. Viewing the multiple meanings of polysemous words as intensions under different contexts, the phenomenon of polysemy fits well in the picture of concepts being functions over contexts. The systematicity is in accord with our claim that these meanings are not grouped under the same word by coincidence, but rather they are governed by the same concept denoted by the word. The seemingly different but related meanings (i.e., intensions, in our terminology) of a word are the function values that are obtained by applying the same concept in various domains (i.e., contexts). When an existing concept is applied to a new domain, it appears as a metaphor at the beginning. After the meaning in the new domain becomes stable and fixed as part of the concept, the concept as a function has been extended to cover its application in one more domain. To that point, the metaphorical flavor may have vanished.

In programming languages, concepts are also functions of intensions ranging over different domains. Programmers are familiar with the notion of operator overloading. For instance, the plus sign "+" can be interpreted as addition of integers or floating numbers, or concatenation of strings, or union of two sets, and so on. Although the interpretations differ in various domains, they systematically share similarity. The "+" sign is under no circumstance interpreted as subtraction of two numbers, which would violate the similarity. The systematical similarity behind the various interpretations is what we called concept. The concept expressed by the symbol "+" has different intensions in various domains (i.e., contexts).

Sometimes, when an existing concept is expanded to a new domain, a new term may be coined. The technical term "phishing" in the web community is such an example. The concept of phishing, originated from the concept of fishing, in the web context has the intension of trapping users into submitting their personal information to a seemingly legitimate website. Observing the connection between phishing and fishing helps to project the understanding of fishing onto the understanding of phishing. Whether it is in one word or two words for two different domains is rather a subjective choice. Had the same word "fishing" been used for the web domain, it would be easier for laymen to know what a "fishing" site is. A new term "phishing" is good to refine the intended concept to the specific domain and hence it is suitable for technical use. However, it would not be as good a choice for such a new term if its morphological connection to its origin were completely cut off.

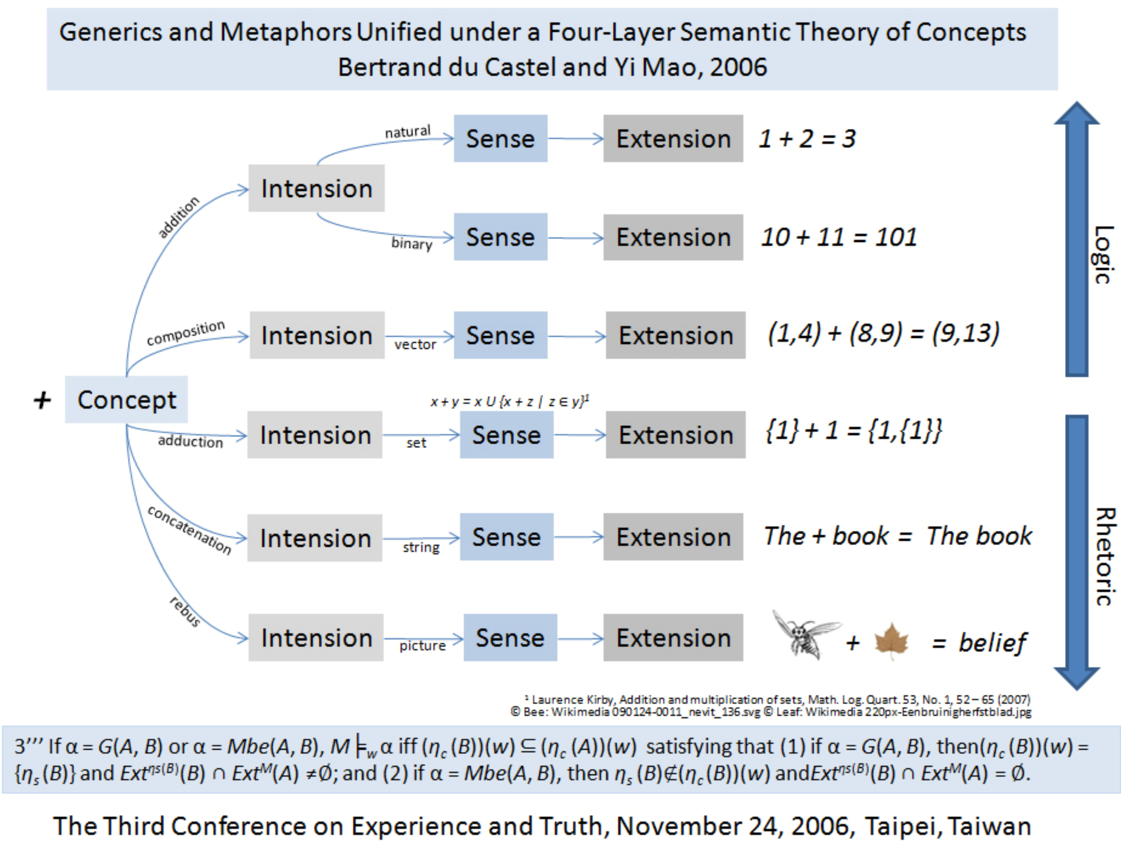

Figure 2 (2011): "+" in the four-layer semantic theory of concepts

2.2 Interpreting Concepts with Montague's Type Theory

Understanding senses and concepts as functions defined on contexts of utterances, we follow the possible world approach used in intensional semantics ([1]) and view possible worlds as logical counterpart of contexts. Hereafter, we will use possible worlds and contexts interchangeably. We formalize the four-layer semantic entities (i.e., extensions, senses, intensions and concepts) in the framework of Montague's type theory ([16]), which links back to Frege's theories on sense, reference ([9]) and concept ([8]) and to Church's type theory of concepts ([2], [3], [4], [5]).

In Montague's type theory, there are three distinct symbols — e, t and s, and two primitive types — e (for entities) and t (for truth values). A functional type $\langle \sigma, \tau \rangle$ can be composed from σ and τ if σ and τ are types. In particular, type $\langle e, t \rangle$ is a set of entities of type e. An intensional type $\langle s, \tau \rangle$ can be constructed from type τ, which is a function from possible worlds to entities of type τ. The entities of type τ are known as the extensions of the intension of type $\langle s, \tau \rangle$ on possible worlds. The relationship between extensions and intensions is captured by the function applications, where extensions are the values obtained by applying intensions to possible worlds. Here the referred extensions and intensions are all in a general and abstract sense. They are not restricted to extensions and intensions of terms. For extensions of terms in particular, we also call them denotations of terms.

Referring to Montague's type theory, we claimed that four-layer semantic entities that a term could mean match up to four different types. Namely, the extension (i.e. denotation) of a term is of type $\langle e, t \rangle$, its sense is of type $\langle s, \langle e, t \rangle \rangle$, its intension is of type $\langle \langle s, \langle e, t \rangle \rangle, t \rangle$, and the concept that the term expresses is of type $\langle s, \langle \langle s, \langle e, t \rangle \rangle, t \rangle \rangle$. Thus, four semantic layers of a term are distinguished in connection with the formal types. Researchers are quite familiar with talking about the denotation and sense of a term as of types $\langle e, t \rangle$ and $\langle s, \langle e, t \rangle \rangle$. Type $\langle e, t \rangle$ is of a set of primitive entities, and the denotation of a term is the set of objects that the term refers. Thus, type $\langle e, t \rangle$ is an exact description of denotations. Type $\langle s, \langle e, t \rangle \rangle$ entities are functions from possible worlds to entities of type $\langle e, t \rangle$, and we understand senses as functions from possible worlds to denotations. Taking the matching between type $\langle e, t \rangle$ and denotations as the basis, the classification of senses to type $\langle s, \langle e, t \rangle \rangle$ is appropriate. Type $\langle \langle s, \langle e, t \rangle \rangle, t \rangle$ covers the sets of entities of type $\langle \langle s, \langle e, t \rangle \rangle$, which are senses in our layered picture. So, intensions, being sets of senses, are of type $\langle \langle s, \langle e, t \rangle \rangle, t \rangle$. The topmost layer of concepts is built upon the layer of intensions of terms through functions defined on possible worlds. As intensions are of type $\langle \langle s, \langle e, t \rangle \rangle, t \rangle$, concepts being functions from possible worlds to intensions are hence of type $\langle s, \langle \langle s, \langle e, t \rangle \rangle, t \rangle \rangle$.

Senses, intensions and concepts have long been confused with each other. It is the novel part of our semantic theory of concepts to claim that (i) an intension is a set of senses; and (ii) concepts are functions from possible worlds to intensions in a similar way as senses are functions from possible worlds to denotations. Interpreting them in the framework of Montague's type theory makes their differences and connections apparent. The sense of a term is solely responsible for determining the denotations of the term in all contexts, but an intension of a term is not directly tied up to the denotations of the term. The intension of a term, being a set of senses, can cover all associated properties (including generic properties) of the term in a certain context.

When the concept expressed by a term is considered under a fixed context (which is often the case), the concept and its intension in this particular context appear to be the same. This explains why they are often confused with each other. However, concepts being functions is well supported by the systematic polysemy and metaphorical use of expressions in multiple contexts. Concepts are no longer traditionally viewed as containers with fixed meanings in them. Rather, they are alive and active, dynamic and distributed. Meanings are constructed with respect to different input contexts. Both generics and metaphors find places to which they belong in the four-layer structure of concepts.

The match-up between the understanding of concepts and Montague's type theory has prepared for us necessary semantic entities to build a theory of semantics in which the truth conditions for generics and metaphors can be interpreted from a unified root — the four-layer structure of concepts.

3. A Unified Semantic Theory for Generics and Metaphors

Mao and Zhou ([15]) have developed a formal semantic theory of metaphors based on the four-layer structure of concepts. The existing semantics is summarized in a sub-section below. We will extend that semantic theory so that it also provides a formal interpretation of generics.

3.1 Formal Interpretation of Metaphors

The formal interpretation of metaphors is developed from a basic claim that metaphors are intensional rather than extensional, as most metaphors under the extensional interpretation are literally false. The semantic interpretation of metaphors formalizes the idea that a metaphor states the intension of its vehicle concept that is included in the intensions of the topic concept under a context common to them.

The logical form of a metaphor is represented as *Mbe(A, B)*, where A and B express the topic concept and the vehicle concept, respectively. The intended reading for *Mbe(A,B)* is "*A* metaphorically is *B*". In some cases, the topic term is about an individual as in "John is a fox" or the vehicle term is a relational predicate as in "My car drinks gasoline". An λ operator is introduced to construct the needed concepts by transforming an object to the property of being this object or from objects to a relation holding among these objects.

Metaphors are formalized in the language L_M that contains the following symbols: (1) a denumerable set of individual variables $Var = \{v_1, v_2, ...\}$, (2) a denumerable set of individual constants $C = \{c_1, c_2, ...\}$, (3) a denumerable set of n-ary ($n \geq 0$) predicate variables $Pred = \{P_1, P_2, ...\}$, (4) an abstraction operator λ, (5) a term connective *Mbe*, (6) two sentential connectives $\neg$ and $\rightarrow$, (7) a universal quantifier $\forall$, and (8) a separator ','. Other connectives $\wedge$, $\vee$, and $\leftrightarrow$, and quantifier $\exists$ can be customarily introduced.

The major components of the semantics for metaphors are *sense space* and *concept space*, which are defined from a given set of possible worlds and a given domain of all possible objects.

Definition 1. (*Sense Space*) Given a set W of possible worlds, a set D of objects, and any n>0, let $SEN(W, D^n) = \{sen \mid sen$ is a function from W to $\wp(D^n)\}$.

Definition 2. (*Concept Space*) Given a set W of possible worlds, a set D of objects, and any n>0, let $CON(W, D^n) = \{con \mid con$ is a function from W to $\wp(SEN(W, D^n))\}$.

The senses of any n-ary predicates or λ expressions and the concepts that they express can be interpreted by semantic entities in $SEN(W, D^n)$ and $CON(W, D^n)$, respectively. Any element in the sense space is a function from possible worlds to sets of objects or vectors of objects. A member from the concept space is a function from possible worlds to sets of senses.

Definition 3. An L_M-model M is a five-tuple $\langle W, D, \sigma, \eta_s, \eta_c \rangle$, where

1. W is a non-empty set of possible worlds;
2. D is a non-empty set of objects;
3. σ is a function that assigns objects to variables (i.e., $\sigma(v)\in D$, for any $v\in Var$);
4. η_s is a sense assignment function such that
   (i) $\eta_s(c)\in D$, for any $c\in C$;
   (ii) $\eta_s(P)\in SEN(W, D^n)$, for any n-ary $P\in Pred$;
   (iii) $\eta_s(\lambda P(Pa_1 \ldots a_n))\in SEN(W, D^n)$ such that $\langle a_1^M, \ldots, a_n^M\rangle\in \eta_s(P)(w)$ in all $w\in W$ (if $a_i\in Var$, $a_i^M=\sigma(a_i)$; else if $a_i\in C$, $a_i^M=\eta_s(a_i)$);
5. η_c is a concept assignment function such that
   (i) $\eta_c(c) = \eta_s(c)\in D$, for any $c\in C$;
   (ii) $\eta_c(P)\in CON(W, D^n)$ satisfying $\eta_s(P)\in \eta_c(P)(w)$ at some $w\in W$, for any n-ary predicate or λ expression P.

In Definition 3, senses and concepts assigned to constant symbols are trivialized to be constant objects from the domain. The constraint for the senses of λ expressions is to ensure that the properties or relations representing them apply back to the object(s) from which they are abstracted. The constraint placed on η_c requires that the sense and concept entities assigned to the same predicate or λ expressions should have some interactions between them. With respect to L_M-model, the truth-value of a formula and the truth condition of the logical form of metaphors in particular can be specified.

Definition 4. Given an L_M-model M, a possible world w and a formula α, we recursively define that α is true at w in M (denoted as $M \models_w \alpha$) in the clauses below.

1. If $\alpha = Pa_1 \ldots a_n$, $M \models_w \alpha$ iff $\langle a_1^M, \ldots, a_n^M\rangle \in \eta_s(P)(w)$;
2. If $\alpha = Mbe(A, B)$, $M \models_w \alpha$ iff $\eta_c(B)(w) \subseteq \eta_c(A)(w)$;
3. If $\alpha = \neg\beta$, $M \models_w \alpha$ iff it is not the case that $M \models_w \beta$;
4. If $\alpha = \beta\rightarrow\gamma$, $M \models_w \alpha$ iff it is not the case that $M \models_w \beta$ or $M \models_w \gamma$;
5. If $\alpha = \forall x\beta$, $M \models_w \alpha$ iff $M(d/x) \models_w \beta$ for all $d\in D$.

The second clause defines the condition under which a metaphor is considered true. The rest are classical truth conditions for connectives and qualification. According to the truth condition for metaphors, "John is a fox" is true at a context w if and only if the properties of foxes such as cunning particularly salient at w are also properties of being John. The reference to a particular context w is necessary to guarantee an appropriate intension that contains only relevant properties for the metaphor and excludes irrelevant properties like having a tail or stealing chicken. Thus, including the intension of foxes at context w in John's character does not require John to have a tail in the meantime.

3.2 Formal Interpretation of Generics

Our basic claim about generics is that a generic statement enriches the intension of its subject term at a context with the sense of its predicate term. The formal interpretation of generics can be easily integrated into the semantics for metaphors with the following addition in syntax and truth condition for generics.

First, we extend the language L_M to include a new term connective G and call the resulting language $L_{M,G}$. The logical form of generics is $G(A, B)$, where A and B express the subject concept and the predicate concept, respectively. *A and B* could be λ expressions that assist to construct the concepts that are talked about in the generic statement.

Second, let $L_{M,G}$-models be the same as L_M-models to keep the same semantic infrastructure. We define the total intension and total extension of a primitive or constructed predicate P in an $L_{M,G}$-model M as stated in Definition 5.

Definition 5. Given an $L_{M,G}$-model $M = \langle W, D, \sigma, \eta_s, \eta_c \rangle$, for any term n-ary predicate or λ-expression P, the extension of P obtained from its sense is $Ext^{\eta_s(P)}(P) = \cup\{(\eta_s(P))(w) \mid w\in W\}$. The total intension of P in the model M is $Int^M(P) = \cup\{\eta_c(P)(w) \mid w\in W\}$ and the extended extension of P in the model M is $EExt^M(P) = \cup\{\cap\{ Ext^{sen}(P) \mid sen\in \eta_c(P)(w)\} \mid w\in W\}$. The total extension of P in the model M is $Ext^M(P) = Ext^{\eta_s(P)}(P) \cup EExt^M(P)$.

According to Definition 5, $Ext^{\eta_s(P)}(P)$ is the union of all extensions that its sense determines at all contexts. The resulting extension is close to the extension under the traditional view. It drives away the notion of context and includes all possible instances of P. As $Int^M(P)$ is the union of all intensions at all contexts, it is context-independent. The total intension of $Int^M(P)$ flats out the functional structure of concepts and blurs the boundary between senses and intensions. It corresponds to the traditional understanding of the concept/intension/sense of P. $EExt^M(P)$ is the extended extension gained by applying the concept expressed by the term P to other domains. For example, if P stands for the binary "close to" relation, then $EExt^M(P)$ contains all pairs of entities that bear the close-to relation in spatial and human relationship domains. $EExt^M(P)$ takes the union of the extension of P in each extended domain, which itself is an intersection of extensions determined by corresponding senses in the intension obtained by applying the concept to that domain. $Ext^M(P)$ is the total extension of P in the model M that contains all extensions both from the original and extended domains.

Third, we extend the conditions of a formula α being true in an $L_{M,G}$-model to cover the case of generics as stated in Definition 6.

Definition 6. Given an $L_{M,G}$-model M, a possible world w and a formula α, we recursively define that α is true at w in M (denoted as $M \models_w \alpha$) in the clauses below.

1. If $\alpha = Pa_1 \dots a_n$, $M \models_w \alpha$ iff $\langle a_1^M, \dots, a_n^M\rangle \in \eta_s(P)(w)$;
2. If $\alpha = Mbe(A, B)$, $M \models_w \alpha$ iff $\eta_c(B)(w) \subseteq \eta_c(A)(w)$;
3. If $\alpha = G(A, B)$, $M \models_w \alpha$ iff $\eta_s(B) \in \eta_c(A)(w)$ and $Ext^{\eta_s(B)}(B) \cap Ext^M(A) \neq \emptyset$;
4. If $\alpha = \neg\beta$, $M \models_w \alpha$ iff it is not the case that $M \models_w \beta$;
5. If $\alpha = \beta\rightarrow\gamma$, $M \models_w \alpha$ iff it is not the case that $M \models_w \beta$ or $M \models_w \gamma$;
6. If $\alpha = \forall x\beta$, $M \models_w \alpha$ iff $M(d/x) \models_w \beta$ for all $d\in D$.

Definition 6 is the same as the Definition 4, except that a new clause is added to specify the truth condition of generics. Clause 3 is a formal way to say that formulas of the form $G(A, B)$, representing generics, are true if the sense of B is included in the intension of A at the context where this generic statement is evaluated and if the sense-determined extension of B overlaps the total extension of A in M. For instance, the generic sentence "Birds fly" states that the birds as a kind, in the worlds where we consider this a true statement, have the associated property of flying and that there are individual birds demonstrating this flying capability. The generics are interpreted intensionally, and play the role of enriching the concept of the subject by adding more properties expressed by predicate to their intension under the context where the generics are stated.

Such an interpretation has a very loose connection interfacing the layer of extension, where the individual objects are the center of focus. Clause 3 only requires that a generic property is exemplified by some individual(s). Generic properties are conceptual rather than extensional. Although "ducks lay eggs" is true, more than half the ducks (e.g., male ducks, ducklings, etc.) indeed do not lay eggs. The number of exceptional cases is not a determining factor in the consideration of the truth-value of generics. Generics contribute to the formation of concepts by extending the intensions of the subject terms that consist of concepts.

On the other hand, Mao ([14]) proposes a canonical reading of generics with subject-predicate *SP* structure as *S* (normally *P*), and if *S* is a plural noun phrase, it can be further refined to be (normal *S*) (normally *P*). Normal objects are selected based on the "meaning" of the subject and predicate terms. The second parameter provides an aspect with respect to which certain objects of a kind are considered normal. The canonical form of generics and its companion truth condition is aimed at accounting for the defeasible feature of inferring that individuals inherit generic properties. This canonical form based interpretation provides the interface between the generic properties and extensions of individuals that may or may not have them. This formalism reflects the formation of generics from exemplary individuals demonstrating generic properties. Generics are applicable to individuals when the normality requirements are meet. This is valuable to guide our daily actions, and people heavily rely on the guidelines stated by law-like generics. The emphasis of this formalism is on the defeasible inference triggered by generics.

These two semantic theories of generics are two sides of one coin. The semantic interpretation of generics given in this paper takes the perspective of specifying their connection to the formation of concepts. The other semantic theory of generics developed in ([14]) tackles the relationship between generics and individuals and accounts for the defeasible link between them. They are complementary to each other, and combined together they paint a complete picture of the role that generics play in the four-layer structure built from extensions up to concepts. Mao and Zhou ([15]) show that the literal meaning of metaphors, which refers to the layer of extension, can be explained in the same semantics that provides metaphorical meaning from the intensional angle. Similarly, two interpretations of generics can be given in the same semantics. While one interpretation stays connected intensionally with concepts, the other reaches out extensions from intension under certain normality constraints. However, we will leave the development of a combined semantics of generics for other occasions. We would rather now focus on revealing the common root of metaphor and generics.

3.3 Unification of Interpretations for Generics and Metaphors

The term connectives *Mbe* and *G* in the formal language $L_{M,G}$ are syntactic markers that activate the corresponding truth condition clause. However, there is no firm boundary separating generics and metaphors in the natural language. We observed from examples in Section 1 that generics and metaphors can have the same syntactical form. More importantly, both of them have to be interpreted intensionally in semantics. They contribute to the formation of concepts. Generics are responsible for building up intensions of concepts in a certain context by adding more senses. Metaphors transfer the intension of a concept in one context to be part of the intension of the concept applied in another domain. They actually have more things in common than their apparent differences. This position is reflected in the semantics that we established for both generics and metaphors.

With a little effort, the truth condition given in Definition 5 for generics $G(A, B)$ can be re-written as

3′. If $\alpha = G(A, B)$, $M \models_w \alpha$ iff $\{\eta_s(B)\} \subseteq (\eta_c(A))(w)$ and $Ext^{\eta_s(B)}(B) \cap Ext^M(A) \neq \emptyset$.

If we ignore the different terminologies used in the literature for the discussions of generics (i.e. subject term and predicate term) and metaphors (i.e. topic term and vehicle term or source and target), then both of them express the inclusion relation between the intensions of two terms in a certain context. The clauses 2 and 3 in Definition 5 can be combined as

3″. If $\alpha = G(A, B)$ or $\alpha = Mbe(A, B)$, $M \models_w \alpha$ iff $(\eta_c(B))(w) \subseteq (\eta_c(A))(w)$ satisfying that if $\alpha = G(A, B)$, then $(\eta_c(B))(w) = \{\eta_s(B)\}$ and $Ext^{\eta_s(B)}(B) \cap Ext^M(A) \neq \emptyset$.

The constraint placed on the interpretation for generics is that the intension of the predicate term under the consideration is a special kind. Namely, it is a singleton set with the sense of the term as its only element. This unified formalism 3″ reflects our view that generics in a very broad sense are metaphors where the metaphorical meanings have been entrenched in the terms as a regular part of the concepts that they express.

If there is a need to require that only novel metaphors should be counted as metaphors, then an opposite semantic constraint may be added for the interpretation of novel metaphors as

3‴. If $\alpha = G(A, B)$ or $\alpha = Mbe(A, B)$, $M \models_w \alpha$ iff $(\eta_c(B))(w) \subseteq (\eta_c(A))(w)$ satisfying that (1) if $\alpha = G(A, B)$, then $(\eta_c(B))(w) = \{\eta_s(B)\}$ and $Ext^{\eta_s(B)}(B) \cap Ext^M(A) \neq \emptyset$; and (2) if $\alpha = Mbe(A, B)$, then $\eta_s(B) \notin (\eta_c(B))(w)$ and $Ext^{\eta_s(B)}(B) \cap Ext^M(A) = \emptyset$.

The novelty of metaphors required in 3‴ is that the topic domain to which the intension of the vehicle domain transfers should be a new one. In other words, entities that fall under the vehicle domain do not belong to the topic domain. For example, the sentence "John is a fox" is genuinely metaphorical only when John is not literally a fox.

Generics extend the territory of intensions of concepts from which metaphorical use may be crafted. The richer the intension, the more directions metaphors may arise in. For example, the following metaphors take the different aspects of being the sun:

(6a) Einstein is the sun.
(6b) Juliet is the sun.
(6c) Chairman Mao is the sun.

Einstein, Juliet and Chairman Mao are all compared to the sun, but they can be the sun due to the different properties of the sun that are stated by the following generics.

(7a) The sun is bright.
(7b) The sun is natural and warm.
(7c) The sun is the center of solar system.

Einstein is the sun because he is bright and his achievement brightens the modern physics. Juliet is the sun to Romeo because she is natural and warm to him as the sun. Chairman Mao is the sun in China because he is the center of the political power. It is possible to build more metaphors from being the sun, if more prototypical properties of the sun are to be acknowledged and spread out by more generic statements about the sun.

The generic properties, being recorded and expressed by generics, serve as the basis for metaphors to emerge. On the other hand, statements that once were metaphorical may also become generic ones, as the phenomenon of the death of metaphors has demonstrated. This process is a slow-moving evolution in the language use, though. The conversion from metaphors to generics only happens after the associated concepts have been expanded to cover the intensions in the domains that were once new as their normal parts.

Our semantic theory clearly shows the common root that generics and metaphors share. It also accounts for their differences and specifies the conditions under which generics become metaphorical and vice versa. Linking back to the examples given in Section 1, it is not surprising that generics and metaphors are really not fundamentally different. Together they constitute a spectrum. Towards the two ends reside novel metaphors and generics. They overlap in the middle ground where generics are also dead metaphors. Generics enrich intensions from which metaphors may generate. The richer the intensions, the more possible metaphors may come alive. Both of them contribute to the construction and formation of concepts. Whether "the sun is bright" is generic and "Einstein is bright" is metaphorical, or the other way around, is biased by and tied up to the history in which the concept is built up. If the sun is the primitive domain where the property of brightness applies and the concept of brightness is later extended to the domain to human characters, then "The sun is bright" is generic and "Einstein is bright" is a metaphor. However, it does not have to be so. Along an equally possible language evolution path, this could be flipped. For example, such flipping is occurring today from "Logicians are smart" to "Nowadays, even automobiles are smart." In addition, with the extended domain of human characters becoming a fixed part of the concept of brightness, "Einstein is bright" can well be a generic statement.

4. Conclusions

We propose a four-layer semantic structure for a linguistic term like "bird" and "bright". Each layer matches up with a semantic entity of a certain type in Montague's intensional semantics. We argue that a linguistic term denotes a sense and a concept, which are functions. For any given context, the sense of the term determines its extensions and the concept denoted by the term specifies its intensions. Intensions are viewed as sets of senses. In this picture, generics extend the intension of the concept expressed by the subject term with the sense of the predicate term, and metaphors transfer part of intension of the vehicle concepts from the established domain to a new domain where the topic concept applies. The results we gain about the semantic interpretation of concepts account for generics and metaphors in a uniform way.

The common features of generics and metaphors as well as their differences are modeled in the four-layer semantics of concepts. We have revealed a unified semantic interpretation under which both generics and metaphors are accounted for. We have also shown the "bridge" connecting generics on the one end and metaphors on the other and conditions of crossing the "bridge" to reach the other end. All of these are done in the framework of a newly developed theory of concepts. The point we would like to deliver in this paper is that generics and metaphors jointly consist of a shifting landscape and that they are not so far apart as they are commonly believed.

5. Future work

The future work lies in two directions. One direction is to gather more evidence for building solid arguments to back up the foundation of the unified semantics given in this paper. The other direction is to demonstrate the significance of this theory by developing its applications in the areas of natural language processing and machine translation.

The four-layer semantic theory of concepts, base of the unified interpretation of generics and metaphors, is quite different from the traditional understanding of what a concept can mean. Although it offers opportunities for us to account for metaphors, generics and their relationship, does it introduce a new set of problems? Questions like the following need to be considered and addressed in future work.

First, how do natural language sentences that take denotations from each layer illustrate four-layer semantic entities? Verbs like "seek" and "look for" are traditionally considered to create intensional contexts to denote intensions. How would this view be affected by the four-layer semantics? As intensions are now differentiated from concepts, what kind of contexts denotes concepts but not intensions?

Second, the *meaning* of words often refers to their intension under the traditional view as there are only two options – extension or intension. After the semantics has been extended to four layers, it is not so obvious which layer should correspond to the meaning of words that is often referred to.

Third, if the words can be interpreted at the different semantic layers, will the meaning compositionality still hold when they are put together to make a sentence? Will some mechanism like, say, type shifting, be needed to maintain the compositionality when the interpretation of words in one sentence crosses multiple layers?

Fourth, the notion of context plays a crucial role in demonstrating that senses as well as concepts are functions. Other than understanding it as a primitive parameter for functions, more analysis needs to be given to reveal the intuition behind the notion of context, in particular in relationship to discourse

Fifth, in the metaphor of "Juliet is the sun", sun attributes like shining, warm and the center of solar system overlap Juliet's character in an apparently indirect way. We cannot literarily say that Juliet, as a person, is shining. "Juliet is shining" and "Juliet is warm" are already metaphorical, compared with the sun. However, via metonymy, a shining face, a warm hand, are not necessarily metaphorical. Some formalization of the structural mapping between the attributes of two objects (i.e., Juliet and the sun) is needed to establish the base of metaphors.

Sixth and finally, the current semantics is static and it only captures a snapshot of the landscape consisting of generics and metaphors at one moment along the time line. It should be extended to a dynamic semantics where the iterative process of evolving from metaphors to generics and from generics to new metaphors can be formalized.

We are convinced that further work on the above mentioned problems and concerns will provide a firmer underlying theory to support the unification of generics and metaphors that we have demonstrated in this paper. We will come back to that point shortly.

Besides the theoretical aspect of the future work, we need to investigate the practical impacts of such a theory on some applications like WordNet (wordnet.princeton.edu) and FrameNet (framenet.icsi.berkeley.edu). Both of them are world leading electronic lexical databases for the English language. Both of them deal with the fact that a word may appear in different senses.

For WordNet, a specific sense of a word is captured by having the word participate in a specific synset (i.e., a specific set of synonyms). The polysemy count of a word is the number of synsets that contain the word. WordNet is used for some Internet search and advertising engines like Google AdSense and Yahoo! ContentMatch (Wikipedia: Wordnet). It helps to disambiguate and expand keywords and to retrieve information online. It is also referenced for building up Web ontologies.

FrameNet, based on frame semantics, documents the range of semantic and syntactic combinatory possibilities of each word in each of its senses. Like WordNet but with different terminology, a sense of a word is called a lexical unit. A given word can have several lexical units (i.e. senses), each of which invokes its own frame. Users in academia as well as in industry use FrameNet for natural language processing, information retrieval and Web ontologies.

The theories that these applications rely on do not have an account for why one word has several senses and what the relationships among senses of the same word are. They treat one word with, say, ten senses as if there were ten different words and each of them has one sense. Our theory of four-layer semantic structure spells out a reason for a word being polysemic. Our theory correctly differentiates the case where a word has several senses from the case where unrelated words are involved. If we were to build applications similar to WordNet or FrameNet based on our theory, then links would have to be added among senses of the same word. It will be interesting to see if modifications introduced to WordNet or FrameNet by our theory lead to an increase of accuracy in Web search results.

In computer science, an ontology is defined as an explicit specification of a concept ([21]). Ontologies are based on monotonic description logics ([22]) for computability. Our model of concepts, active and dynamic by its unification of generics and metaphors, provides a new foundation for the elaboration of non-monotonic ontologies in knowledge acquisition.

Finally, we need to reinforce the understanding that since our goal was to demonstrate the unification of generics and metaphors in a single framework, we have strived to keep this framework as close as possible to the set theory based classical semantics, the same thread of semantics that didn’t account for the similarities of generics and metaphors in more than two thousand years. We are aware that relieving this epistemological pressure and reversing the proposition, i.e. considering generics and metaphors unified as a starting point, could lead to major expansions, and improvements, or our unifying four-layer semantics. We are eagerly expecting these developments, hoping that they will lead to new progress, starting with understanding the unified nature of generics and metaphors in both scaling down towards morphology and up towards the integration of context and discourse.

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Revisions:

Original publication:
November 24, 2006 at the Third Conference On Experience and Truth, November 24, 2006, Taipei, Taiwan.
Amended:
July 28, 2011, Austin, Texas, USA, and Beijing, People's Republic of China.
Updated versions are posted at:
http://knol.google.com/k/generics-and-metaphors-unified-under-a-four-layer-semantic-theory-of-concepts.