Mechanisms of Figurative Use

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Abstract

Reference with the sign kind *symbol*[1] is modeled in Database Semantics (DBS) as an agent-internal pattern matching between the language and the context level, based on the type-token relation. For example, the concept type dog at the language level matches a concept token dog at the context level.

But what about a nonliteral (figurative) use, such as referring to a dog with the concept animal or to an orange crate with the concept table? It is proposed to relate the literal referent and the nonliteral concept by means of an inference which applies before pattern matching in the speak mode and after pattern matching in the hear mode, thus maintaining a standard type-token pattern matching. The paper proceeds systematically from nonliteral uses of nouns to those of verbs and adjectives.

Key words:
onboard orientation system; hear, think, speak mode; content-pattern conversion; inductive, deductive, abductive inference; type, token; reference

1 Introduction

DBS models the cycle of natural language communication as a declarative software system for a talking robot which can switch between the hear mode, the think mode, and the speak mode. The hear mode maps modality-dependent unanalyzed language surfaces (raw input) into cognitive content which is stored in the agent's artificial memory (data base). The think mode (i) selectively activates content by navigating along the semantic relations between elementary contents and (ii) derives new content from activated content matching the antecedent (induction) or the consequent (abduction) of inferences. The speak mode takes activated content as input and uses lexicalization rules to realize language-dependent surfaces as raw unanalyzed output.

A content is represented as a set of nonrecursive (flat) feature structures with ordered attributes,[2] called proplets (because they are the elementary items of propositions–in

[1] In concord with Peirce (CP 2.228, CP 2.229 and CP 5.473), words like book, run, or fast are called symbols, in contradistinction to indexicals like you or now.

[2] The feature structures used in today's linguistics (e.g. GPSG, LFG, HPSG) are the direct opposite, i.e. recursive with unordered attributes (Carpenter 1992)

analogy to droplet). The semantic relations of structure connecting the proplets in a content are defined by address. This makes proplets order-free, which is essential for accommodating the storage and retrieval mechanism of the artificial agent's memory.

A content proplet is turned into a pattern by replacing one or more constant values with variables (4.2, 4.3). The computational matching between pattern and content proplets is efficient because proplets are nonrecursive and their attributes are ordered. Pattern matching is used in the application of operations to content (e.g. 2.1), the extraction of information from memory (CLaTR Sect. 5.4), and the definition of reference as a relation between contents in the agent's cognition (CTGR).

The concepts of a nonlanguage content are reused as the elementary meanings of a language content: language and context proplets are alike except that language proplets have a language-dependent surface[3] while context proplets do not. Using the same semantic relations for language content and context content makes the interaction between the two kinds of content simple and direct. Because reference may also occur without language, as when recognizing something seen before, content used for reference is called the language level regardless of whether the proplets happen to contain surface values or not (generalized reference, CTGR).

2 Induction, Deduction, Abduction

As an introduction to DBS inferencing, let us review reasoning based on logic. C.S.Peirce associated the logical method with three phases of scientific inquiry.

Induction is the step from a repeated observation of the same correlation, e.g. A & B, to the assumption that if A then B holds in general. However, even if the same correlation has been observed a thousand times, there remains an element of probability: there is no *guarantee* that the induction if A then B might not fail the next time.

Deduction guarantees the conclusion if the premise(s) is/are fulfilled. This is because deduction is based on the *form* of a correlation, and not on the observation of contingent facts. For example, in the predicate calculus of symbolic logic

$$\forall x[f(x) \rightarrow g(x)] \Rightarrow \exists x[g(x) \wedge f(x)]$$

is guaranteed to hold[4] regardless of what f and g might stand for.

Abduction (also called retroduction) is the hypothetical guess at the best explanation. Like induction, it has an element of probability. For example, if Fido seems to always bark when a stranger approaches (2.2) and Fido now happens to bark, then it is not unlikely that a stranger is approaching.

In summary, as Peirce (1903)[5] famously put it

> Deduction proves that something must be; Induction shows that something actually is operative; Abduction merely suggests that something may be.

[3] Examples of different language-dependent surfaces for the same concept are dog, chien, Hund, and cane.

[4] Provided that the extension of f in the universe of discourse is non-empty, which is usually assumed.

[5] As contemporaries with overlapping research areas, especially in their contribution to quantification theory, Peirce (1838–1914) and Frege (1848–1925) raise the question of whether they knew of each other's work; after all, Peirce visited Europe five times between 1870 and 1883 on assignment for the US Geological Service. It appears that no conclusive answer has been found (Hawkins 1993).

How does this characterization in terms of logical modality, i.e. necessary fact (deduction), contingent fact (induction), and possible fact (abduction), relate to DBS inferencing?

DBS not only welcomes Peirce's association of inductive, deductive, and abductive reasoning with the scientific method of inquiry, but continues with the additional step of tracing the scientific method back to the reasoning of individual cognitive agents. This is motivated as follows:

A scientific method of inquiry would have little chance of being accepted if it did not concur with the natural reasoning of the scientists and their audience, who are all individuals. The methods of scientific inquiry must be available to them in principle because otherwise they could not follow, and therefore would not accept, a scientific argument. This is the recognition side of the scientific method.

The action side, in contrast, is the use of the scientific method for modeling rational behavior. The goals are maintaining balance and optimizing survival in the agent's ecological niche, whatever it may be.[6] Instead of truth, the standard of success is the survival of the agent as a precondition for reproduction (Darwin 1859).

A reconstruction of Peirce's induction, deduction, and abduction must take the following differences between the logical method and DBS into account. First, propositions in DBS are contents defined as sets of proplets containing concepts and connected by address (in contradistinction to logical expressions, which denote truth values and use linear order to connect their elements). Second, quantifiers are absent and their contribution to truth-conditions is treated alternatively as the determiners of a content (NLC, Sect. 6.4).

Third, DBS uses the same kinds of inference in the three stages of scientific inquiry. The purpose of an induction is the derivation of a reasonable deduction, and the purpose of a deduction is its role as a step in reasoning. The validity of a DBS deduction does not derive from its form, but is evaluated in terms of how successfully the agent behaves in its ecological niche. For example, if the agent observes that Fido seems to always bark when a stranger approaches, this DBS induction may crystalize into a deduction which is believed by the agent to be a general rule:

2.1 Using a DBS inference for deduction

$$
\begin{array}{lccccc}
\textit{pattern level} & \begin{bmatrix}\text{noun: stranger}\\ \text{fnc: approach}\\ \text{prn: K}\end{bmatrix} & \begin{bmatrix}\text{verb: approach}\\ \text{arg: stranger}\\ \text{prn: K}\end{bmatrix} & \Rightarrow & \begin{bmatrix}\text{noun: fido}\\ \text{fnc: bark}\\ \text{prn: K+1}\end{bmatrix} & \begin{bmatrix}\text{verb: bark}\\ \text{arg: fido}\\ \text{prn: K+1}\end{bmatrix}\\
 & \Uparrow & & & \Downarrow & \\
\textit{content level} & \begin{bmatrix}\text{noun: stranger}\\ \text{fnc: approach}\\ \text{prn: 23}\end{bmatrix} & \begin{bmatrix}\text{verb: approach}\\ \text{arg: stranger}\\ \text{prn: 23}\end{bmatrix} & & \begin{bmatrix}\text{noun: fido}\\ \text{fnc: bark}\\ \text{prn: 24}\end{bmatrix} & \begin{bmatrix}\text{verb: bark}\\ \text{arg: fido}\\ \text{prn: 24}\end{bmatrix}
\end{array}
$$

A DBS inference is used deductively if the input matches the antecedent such that the output is derived by the consequent; it is used abductively, in contrast, if the input

[6] Providing the autonomous behavior control of a cognitive agent with rational behavior does not preclude the modeling of irrational behavior. All that is required for leading the reasoning machine astray is the introduction of irrational beliefs.

matches the consequent and the output is derived by the antecedent.

Going from the consequent to the antecedent by traversing the $\Rightarrow$ in the opposite direction, upstream so to speak, is interpreted as a weakening of the output to the status of a mere hypothesis. For example, the abductive application of 2.1 in 2.2 does not guarantee that a stranger is approaching – Fido may be barking for other reasons.

Formally, an abductive use differs from a deductive use by the position of the $\Uparrow$ and $\Downarrow$ between the pattern and the content level:

2.2 Using a DBS inference for abduction

$$
\begin{array}{l}
\begin{array}{l} \textit{pattern} \\ \textit{level} \end{array}
\begin{bmatrix}\text{noun: stranger}\\ \text{fnc: approach}\\ \text{prn: K}\end{bmatrix}
\begin{bmatrix}\text{verb: approach}\\ \text{arg: stranger}\\ \text{prn: K}\end{bmatrix}
\Rightarrow
\begin{bmatrix}\text{noun: fido}\\ \text{fnc: bark}\\ \text{prn: K+1}\end{bmatrix}
\begin{bmatrix}\text{verb: bark}\\ \text{arg: fido}\\ \text{prn: K+1}\end{bmatrix}
\\
\qquad\qquad\qquad\qquad\quad \Downarrow \qquad\qquad\qquad\qquad\qquad\qquad \Uparrow
\\
\begin{array}{l} \textit{content} \\ \textit{level} \end{array}
\begin{bmatrix}\text{noun: stranger}\\ \text{fnc: approach}\\ \text{prn: 23}\end{bmatrix}
\begin{bmatrix}\text{verb: approach}\\ \text{arg: stranger}\\ \text{prn: 23}\end{bmatrix}
\quad
\begin{bmatrix}\text{noun: fido}\\ \text{fnc: bark}\\ \text{prn: 24}\end{bmatrix}
\begin{bmatrix}\text{verb: bark}\\ \text{arg: fido}\\ \text{prn: 24}\end{bmatrix}
\end{array}
$$

In this abductive application of the inference stranger approaches $\Rightarrow$ fido bark the double rightarrow is traversed upstream, from right to left. The double arrow in an abductive application may be shown graphically as $\stackrel{\curvearrowleft}{\longrightarrow}$, e.g. 6.3.

3 Content-Pattern Conversion

The operations of the DBS hear, think, and speak mode have in common that they are defined as pattern proplets which take matching content proplets as input ($\Uparrow$) and derive ($\Rightarrow$) matching content proplets as output ($\Downarrow$). Pattern matching is controlled by the following constraint:

3.1 Matching Constraint

1. Attribute condition
   The attributes of the pattern proplet must be a sublist (equal or less) of the attributes of a matching content proplet.

2. Value condition
   Each value of the pattern proplet must be compatible with the corresponding value of the matching content proplet.

Based on empirical research, the value condition may controlled precisely by defining *variable restrictions* as sets specifying the values which a variable may be bound to (codomain).

The use of restricted variables allows us to automatically convert any content into a strictly equivalent pattern (method one) and any pattern into strictly equivalent contents (method two). Consider the following example of a pattern matching the content corresponding to Every child slept with extended variable restrictions:

3.2 Conversion between pattern and contents

pattern

noun: α	verb: β
cat: snp	cat: #n′ decl
sem: pl exh	sem: past
fnc: β	arg: α
mdr:	mdr:
nc:	nc:
pc:	pc:
prn: K	prn: K

where α ε {man, woman, child}, β ε {sleep, sing, dream}, and K ε $\mathbb{N}$

$\Longleftrightarrow$

contents

Every man slept.	Every man sang.	Every man dreamed.
Every woman slept.	Every woman sang.	Every woman dreamed.
Every child slept.	Every child sang.	Every child dreamed.

The contents are generated from the pattern by systematically replacing the variables α and β with elements of their restriction sets. The ε operator connecting a variable with its restriction set is used here in the interpretation "may be instantiated as."

4 Learning from a Single Observation

Learning, i.e. the agent's adaptation to novel changes in its ecological niche, may be based on a recurrent experience, but also on a single observation (Bandura 1986). Consider the observation John brought Mary flowers and she smiled as a nonlanguage content:

4.1 Content as a set of concatenated proplets

sur: john	sur:	sur: mary	sur:
noun: (person x)	verb: bring	noun: (person y)	noun: flower
cat: snp	cat: #n′ #d′ #a′ decl	cat: snp	cat: pnp
sem: nm m	sem: past	sem: nm f	sem: indef pl
fnc: bring	arg: (person x) (person y) flower	fnc: bring	fnc: bring
mdr:	mdr:	mdr:	mdr:
nc:	nc: (smile 28)	nc:	nc:
pc:	pc:	pc:	pc:
prn: 27	prn: 27	prn: 27	prn: 27

sur: mary	sur:
noun: (person y)	verb: smile
cat: snp	cat: #n′ decl
sem: nm f	sem: past
fnc: smile	arg: (person y)
mdr:	mdr:
nc:	nc:
pc:	pc:
prn: 28	prn: 28

The content consists of two propositions which are concatenated by an extrapropositional coordination. Defined as nonrecursive feature structures with ordered attributes, proplets serve as the computational data structure of DBS.

The proplets of an elementary proposition are held together by a shared prn (for proposition number) value, here 27 and 28. The semantic relations within the first proposition are john/bring (subject/predicate), mary\bring (indirect_object\predicate) and flower\bring (direct_object\predicate). The propositions are connected by the nc (next conjunct) value of *bring*.

The first step of turning this content into a DBS inference is transforming it into a pattern by replacing certain constants with variables using simultaneous substitution. The least abstract pattern results from substituting only the prn values with variables

4.2 Least abstract pattern derived from 4.1

$$\begin{bmatrix}\text{noun: john}\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{verb: bring}\\ \text{cat: \#n}'\ \text{\#d}'\ \text{\#a}'\ \text{decl}\\ \text{arg: john mary flower}\\ \text{nc: (smile K+1)}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: mary}\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: flower}\\ \text{cat: pnp}\\ \text{sem: indef pl}\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: (mary K)}\\ \text{fnc: smile}\\ \text{prn: K+1}\end{bmatrix}\begin{bmatrix}\text{verb: smile}\\ \text{cat: \#n}'\ \text{decl}\\ \text{arg: (mary K)}\\ \text{prn: K+1}\end{bmatrix}$$

Compared to 4.1, the proplets are simplified to show the relevant semantic relations.

The pattern may be generalized by also replacing the constants john and mary with variables using simultaneous substitution:

4.3 Pattern with increased abstraction

$$\begin{bmatrix}\text{noun: }\alpha\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{verb: bring}\\ \text{cat: \#n}'\ \text{\#d}'\ \text{\#a}'\ \text{decl}\\ \text{arg: }\alpha\ \beta\text{ flower}\\ \text{nc: (smile K+1)}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: }\beta\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: flower}\\ \text{cat: pnp}\\ \text{sem: indef pl}\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: (}\beta\text{ K)}\\ \text{fnc: smile}\\ \text{prn: K+1}\end{bmatrix}\begin{bmatrix}\text{verb: smile}\\ \text{cat: \#n}'\ \text{decl}\\ \text{arg: (}\beta\text{ K)}\\ \text{prn: K+1}\end{bmatrix}$$

This pattern may be used to classify different events of the same kind stored in the agent's memory, defined as a content-addressable word bank (CLaTR) Sect. 4.1.

To turn the pattern 4.3 into an inference, the extrapropositional coordination connecting the two propositions must be replaced by a connective. For automation, the connective used is generic ⇒:

4.4 Turning a pattern into a DBS inference

$$\begin{bmatrix}\text{noun: }\alpha\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{verb: bring}\\ \text{cat: \#n}'\ \text{\#d}'\ \text{\#a}'\ \text{decl}\\ \text{arg: }\alpha\ \beta\text{ flower}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: }\beta\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix}\begin{bmatrix}\text{noun: flower}\\ \text{cat: pnp}\\ \text{sem: indef pl}\\ \text{fnc: bring}\\ \text{prn: K}\end{bmatrix} \Rightarrow \begin{bmatrix}\text{noun: (}\beta\text{ K)}\\ \text{fnc: smile}\\ \text{prn: K+1}\end{bmatrix}\begin{bmatrix}\text{verb: smile}\\ \text{cat: \#n}'\ \text{decl}\\ \text{arg: (}\beta\text{ K)}\\ \text{prn: K+1}\end{bmatrix}$$

An agent may use such an inference in recognition and in action. In recognition, the inference serves to pick out corresponding contents from memory. In action, the inference is used for imitating what has been observed by applying its antecedent to a current situation and expecting the output resulting from the consequent.

5 STAR: the Agent's Onboard Orientation System

A context of interpretation in the narrow sense is the current state of the agent's onboard orientation system, called the STAR. In the wide sense, it consists of those contents in the agent's entire memory which *resonate* with the current content (CLaTR Sect. 5.4).

The STAR of a content token is defined as a proplet with the attributes S(pace), T(ime), A(gent), R(ecipient), 3rd, and prn. These attributes take the following values:

5.1 Values of the STAR attributes

- The S attribute specifies the agent's current location.
- The T attribute specifies the agent's current moment of time.
- The A attribute specifies the agent itself[7]
- The R attribute specifies the intended recipient (partner of discourse).
- The 3rd attribute specifies items which are neither first nor second person.
- A STAR and a content are linked by a shared prn value.

The last two attributes are omitted in the name of the agent's onboard orientation system for the sake of a simple and memorable acronym.

The values of the S attribute are provided by agent-external landmarks like a big rock or a street sign, but may also be GPS data which are radio-transmitted directly into an artificial agent's cognition. The values of the T attributes are provided by agent-external landmarks like the changes of day and night or clocks observed by the agent (CLaTR Sect. 14.2), but may likewise be radio-transmitted directly into an artificial agent's cognition. The A value is the fixpoint of the agent's cognition and does not change. The R and 3rd values result from the agent's recognition in the interaction with other agents or items. The prn value is provided by the STAR to the associated content.

For different perspectives on content, three basic STARs are distinguished, called STAR-0, STAR-1, and STAR-2.[8] The agent's non-language recognitions and actions are recorded in their temporal order by a sequence of STARs-0 or "STARs of Origin."

5.2 STAR-0 content: I see a mouse

sur:	sur:	sur:	S: kitchen
noun: pro1	verb: see	noun: mouse	T: Monday
cat: s1	cat: #n-s3′ #a′ decl	cat: snp	A: john
sem: sg	sem: pres	sem: def sg	R:
fnc: see	arg: pro1 mouse	fnc: see	3rd:
mdr:	mdr:	mdr:	prn: 34
nc:	nc:	nc:	
pc:	pc:	pc:	
prn: 34	prn: 34	prn: 34	

A STAR and its content are connected by sharing their prn value. The indexical pro1 points at the A value john. A STAR-0 content does not involve language.

[7] Such self-reference is essential for recognizing oneself in a mirror (mirror test, Gallup 1970).

[8] A detailed presentation was published as CTGR.

When John tells Mary I saw a mouse, the perspective is from his current STAR-0 back onto STAR-0 content of origin 5.2.

5.3 STAR-1 content of the speaker

sur:	sur:	sur:	S: living room
noun: pro1	verb: see	noun: mouse	T: Tuesday
cat: s1	cat: #n$'$ #a$'$ decl	cat: snp	A: john
sem: sg	sem: past	sem: def sg	R: mary
fnc: see	arg: pro1 mouse	fnc: see	3rd:
mdr:	mdr:	mdr:	prn: 45
nc:	nc:	nc:	
pc:	pc:	pc:	
prn: 45	prn: 45	prn: 45	

The S, T, R, prn values are contributed by the current STAR-0. The A value is that of the STAR-0 of origin. The verb is changed into the past tense.

The hearer's perspective onto the speaker's STAR-1 content is called a STAR-2 content. In a STAR-2 content, pro1 is changed into pro2 and vice versa, and the A and the R of the STAR-2 are inverted. Also, if the STAR-1 content's verb's sem value happens to be pres and the T-value of the STAR-2 is later than that of the STAR-1, the verb's sem must be changed to past. The result of the transition from the speaker's STAR-1 content to the hearer's STAR-2 content may be shown as follows:

5.4 STAR-2 content of the hearer

sur:	sur:	sur:	S: living room
noun: pro2	verb: see	noun: mouse	T: Tuesday
cat: s2	cat: #n$'$ #a$'$ decl	cat: snp	A: mary
sem: sg	sem: past	sem: def sg	R: john
fnc: see	arg: pro2 mouse	fnc: see	3rd:
mdr:	mdr:	mdr:	prn: 23
nc:	nc:	nc:	
pc:	pc:	pc:	
prn: 23	prn: 23	prn: 23	

The prn value of the hearer is unrelated to that of speaker because individual agents have their own prn counters. The indexical pro2 points at the R value.

6 Hypernym/Hyponym Metaphor

DBS inferences serve not only in reasoning and behavior control, but also in the interpretation of the nonliteral uses of content. An example of a figurative or nonliteral use is referring with the content The animal is tired to the dog sleeping by the stove. For communication to succeed, this requires the speaker's STAR-0 STAR-1 conversion to go from the concept dog to the hypernym animal and the hearer's STAR-1 STAR-2 conversion from the hypernym animal back to dog.

Hypernymy and hyponymy are classical meaning relations in the lexicon and may be formally treated by the following DBS inferences:

6.1 Hypernymy as a lexical S-inference

[noun: α] $\Rightarrow$ [noun: β]
if α ε {ape, bear, cat, dog, ...}, then β is animal,
if α ε {apple, peach, pear, salad, ...}, then β is food,
if α ε {bush, cactus, flower, grass, tree, vine, ...}, then β is plant,
...

The relation between the instantiations and their hypernyms is coded by extended variable restrictions.

The inference implementing a hyponymy, in contrast, takes a higher term, e.g. animal, as input and renders the set of instantiations, e.g. ape, bear, cat, dog, ..., as output:

6.2 Hyponymy as a lexical S-inference

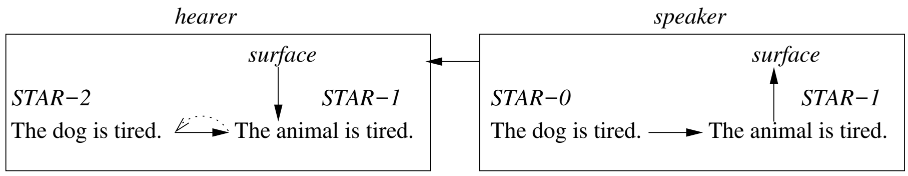
[noun: β] $\Rightarrow$ [noun: α]
if β is animal, then α ε {ape, bear, cat, dog, ...},
if β is food, then α ε {apple, peach, pear, salad, ...}
if β is plant, then α ε {bush, cactus, flower, grass, tree, vine, ...}
...

The relation between the higher term and its instantiations is coded by extended variable restrictions.

Hypernymy and hyponymy are symmetric in that for every hypernymy there is a corresponding hyponymy and vice versa. Such symmetry may not be found in the other classical pair of lexical relations, namely synonymy and antonymy.

To treat the mapping from a lower term to a higher term in the speak mode and from the higher term to the lower term in the hear mode, let us use 6.1 deductively in the speak mode and abductively in the hear mode.

6.3 Double STAR conversion based on hypernym relation



Using the same inference in the speak and the hear mode, but deductively in the speak and abductively in the hear more models the hearer's predicament of having to correctly select that element in the instantiation set (variable restriction on α in 6.1) from which the speaker had proceeded to the hypernym.

In the speak mode, the initial matching is from the input token to the antecedent variable ($\Uparrow$). This is shown informally by the following deductive application of the hypernymy inference:

6.4 Deductive use of hypernymy inference (speak mode)

inference:	α	$\Rightarrow$	β
	$\Uparrow$		$\Downarrow$
content:	dog is tired		animal is tired

The inference applies in the forward direction to render the hypernym animal as the output of the consequent.

In the hear mode, in contrast, the initial matching is from the input token to the variable of the consequent ($\Uparrow$). This is shown informally by the following abductive application of the hypernymy inference 6.1:

6.5 Abductive use of hypernymy inference (hear mode)

inference:	α		β
	$\Downarrow$		$\Uparrow$
content:	dog is tired		animal is tired

The inference applies in the backward direction (against the stream) to render the possible instantiation dog as the output of the antecedent.

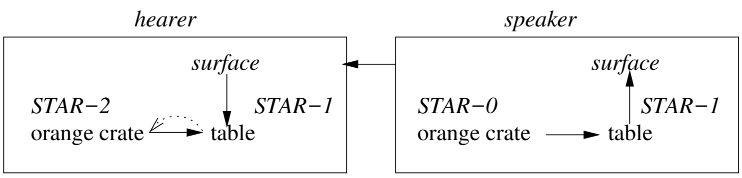
7 Property Sharing Metaphor

Another kind of figurative noun use has been called a *property sharing metaphor* (Glucksberg 2001 p. 58). Consider the following scenario (FoCL Sect. 5.2): a hearer holding a coffee pot has just entered a room containing nothing but an orange crate. If the speaker requests Put the coffee on the table!, the hearer will infer that table is used to refer to the crate.

However, if a prototypical table were standing next to the orange crate, the hearer would interpret the sentence differently, putting the coffee not on the crate, but on the table. This is not caused by a change in the meaning$_1$ (i.e. the type) of the word table, but by the fact that the context of use has changed, providing an additional and more suitable candidate for best match.

In contrast to the previous example, there is no hyper-hypo (6.1, 6.2) relation between *table* and *orange crate*. Instead, the nonliteral use of *table* is based on another STAR-0 STAR-1 conversion in the speak mode and STAR-1 STAR-2 conversion in the hear mode:

7.1 Double STAR conversion based on shared property



The conversion is based on the following inference:

7.2 Property sharing inference

α has flat surface $\Rightarrow$ α may serves as table
where α ε {commode, footrest, low bookshelf, orange crate, ...}

The speak mode uses 7.2 deductively by going from the antecedent to the consequent:

7.3 Deductive use of property sharing inference

inference:	α has flat surface $\Rightarrow$	α may serve as table
	$\Uparrow$	$\Downarrow$
content:	orange_crate	orange_crate

The referent orange_crate is bound to the variable α in the antecedent, enabling the consequent to characterize it as a possible table.

The hear mode, in contrast, uses 7.2 abductively by going from the consequent to the antecedent of the inference.

7.4 Abductive use of property sharing inference

inference:	α has flat surface ⟵⟶	α may serve as table
	$\Downarrow$	$\Uparrow$
content:	orange_crate	orange_crate

The concept *table* is attached to the sign's surface. The abductive use provides the hearer with a reason of why the speaker might have selected the term table for an orange crate, which helps to find the intended referent.

As in all abductive use, there is no certainty in the hear mode. For example, if the orange crate were accompanied by a commode, a footrest, and a low bookshelf, it would be impossible for the hearer to decide what the speaker meant with "table" (too many candidates with flat horizontal surfaces in the current context of interpretation, embarrassment of riches). In such a case, the speaker would have to specify more precisely what is meant in order for communication to succeed .

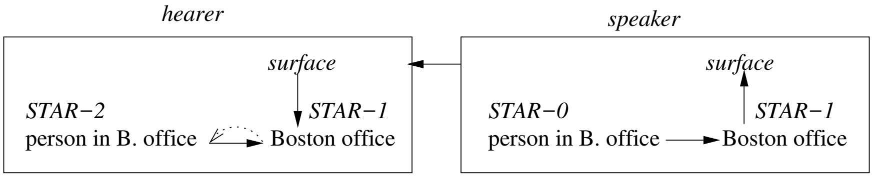
8 Nonliteral Use based on a Metonymy

Another nonliteral use of classical rhetoric besides metaphor is metonymy. Roughly speaking, a metonymy is based on a part-whole relation,[9] as when using the location Washington to refer to the US government, the feature black beard to refer to a person with a black beard, the abridment Mexico's renewable plants (CNN) for Mexico's renewable energy power plants, or the term Boston office to refer to a person working in the Boston office.

Like the figurative use of the hypernymy (Sect. 6) and shared property (Sect. 7) relations, a figurative use based on a metonymy is based on a STAR-0 STAR-1 conversion in the speak mode and a STAR-1 STAR-2 conversion in the hear mode:

[9] Metonymy is a kind of meronymy.

8.1 Double STAR conversion based on metonymy relation



The conversion is based on the following inference:

8.2 Part-whole inference

α is person working in Boston office $\Rightarrow$ α is Boston office

In the speak mode, the inference is used deductively:

8.3 Deductive use of metonymy inference

inference:	α is person w. in Boston office $\Rightarrow$	α is Boston office
	$\Uparrow$	$\Downarrow$
content:	person working in Boston office	Boston office

In the hear mode, the inference is used abductively:

8.4 Abductive use of metonymy inference

inference:	α is person w. in Boston office ⇠	α is Boston office
	$\Downarrow$	$\Uparrow$
content:	person working in Boston office	Boston office

The abductive use of 8.4 restores the abbreviation into the long version.

An alternative sign-based analysis of this metonymy example is presented by Hobbs et al. (1993). Alternative to the DBS definition of meaning as content, they define *understanding* in terms of truth:

> "The interpretation of a text is the minimal explanation of why the text would be true."

The approach is illustrated with an analysis of the expression The Boston office called.

First the sentence is translated manually into a formula of predicate calculus:

8.5 Formal representation of The Boston office called.

$(\exists$ x, y, z, e$)$*call′*(e,x) $\wedge$ person(z) $\wedge$ *rel*(x,y) $\wedge$ *office*(y) $\wedge$ *Boston*(z) $\wedge$ *nn*(z,y)

Then an agent-external but mutual knowledge base is filled with six *facts*, one for each conjunct, e.g. *Boston*(B_1) = B_1 *is the city Boston* and *nn*(z,y) = *if* y *is in* z*, then* y *and* z *are in a possible compound nominal relation*. Finally, a parser takes the formula 8.5 as input to check its truth-value relative to the knowledge base. This sign-based procedure uses English as the metalanguage (FoCL Sect. 19.4) and is equated with language understanding.

9 Nonliteral Uses of Verbs

Nonliteral use is not limited to nouns, as shown by the verb *hit* in The voters are hitting the polls, A cold beer hits the spot, or The marines hit the beach. However, while the nonliteral use of nouns requires a literal counterpart insofar as the *intended referent* must be established in order for communication to succeed, this is neither necessary nor even always possible in the nonliteral interpretation of verbs.[10]

For example, one would be hard pressed to instantly provide the verb in the following examples with a literal counterpart:[11]

9.1 Nonliterally used verbs

John stole the show.
John plays the market.

In as much as the transitively used verbs establish a *relation* between John and market, and John and show, respectively, there does not exist a *referent* for verbs. Consequently, there is neither the possibility nor the necessity (for communication to succeed) to find a literal referent.

This holds regardless of whether the direct object of a metaphoric relation is concrete or abstract, as shown by the following example:

9.2 Metaphoric action relation

John gave Mary an idea.
Let me give you an idea of what I mean!

As in all action verbs, the operational definition of the concept give has two sides, one for recognition, the other for action (self-performance, Sect. 4). Because noun concepts with (e.g. book) and without (e.g. idea) concrete external counterparts are processed the same in the agent's cognition, the action side of the operational definition of *give* is sufficient in the production and interpretation of the examples in 9.2.

There are also concepts like *melt* in which the operational definition of the intransitive use may be limited to the recognition side, as in the following example from NatGeo Wild, *Secrets of Wild India*, 2012:

[10] Whether or not figurative language (i) always has a literal counterpart which is (ii) required for understanding is discussed controversially in the literature (Ricoeur 1975). In DBS, the answer is "yes" for nouns and "no" for verbs.

[11] This holds independently of their conventionalized use because they may be understood immediately at first hearing.

9.3 Metaphoric recognition relation

The tiger melts back into the grass.

Accompanied by vivid TV images of the tiger becoming invisible (quasi dissolving), there is no need to find a “literal” counterpart for *melt*. In other words, *melt* is used here directly, like *steal* and *play* in 9.1. Without a literal counterpart, inferencing is absent in the direct figurative use of verbs.

Before moving to the figurative use of modifiers in the following two sections, let us note a difference between a figurative use (i) having a literal *referent* and (ii) having a literal *counterpart*. Verbs and modifiers are alike in that they do not have referents because they denote relations or properties. They differ, however, in that figurative verbs are used directly in the sense that they lack a literal counterpart, unlike 6.3, 7.1, and 8.1. Figurative modifiers, in contrast, do have a literal counterpart, as shown in 10.2 and 11.2.

The figurative use of verbs is the only class which does not have a literal counterpart. Because verbs (predicates) stand for whole propositions, the literal counterparts of nonliterally used verbs are propositions rather than single content words.

10 Figurative Use of an Adnominal Modifier

Modifiers are optional in the sense that a sentence continues to be grammatically complete if a modifier is removed. Modifiers have meaning (i.e. they are autosemantica) and serve to narrow the matching conditions of the modified. In adnominal use, modifiers contribute to the reference specification of the modified noun, but do not refer by themselves (CTGR).[12]

For example, the adnominal adjective blue in Mary wore a blue dress helps to distinguish the referent *dress* from other candidates with other properties, such as Mary wore a red dress. Also, the sentence Mary wore a dress, i.e. without the adnominal, is still grammatically complete.

Like nouns (Sects. 6–8) and verbs (Sect. 9), modifiers may be used figuratively. Consider the figurative use of the adnominal adjective great in the following example:

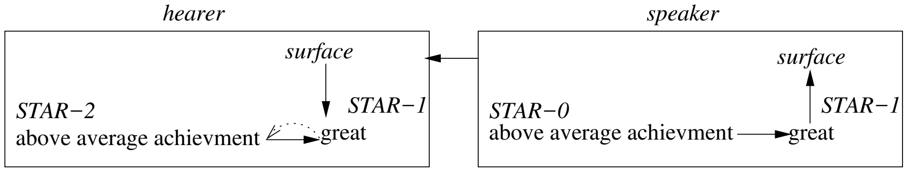
10.1 Figurative use of great

Booth shot a great man.

Referring to the assassination of President Lincoln by J.W.Booth in 1865, the use of great in this example does not apply to the referent’s physique (though Lincoln was tall), but to achievements far greater than average. This figurative use is based on a STAR-0 STAR-1 conversion in the speak mode and a STAR-1 STAR-2 conversion in the hear mode:

[12] When a modifier is nominalized, however, as in this red is darker than this, it does refer (CLaTR 6.6.7).

10.2 Double STAR conversion for figurative adnominal



The conversion is based on the following inference:

10.3 Inference coding a figurative use of great

> α's achievement as β is greater than average $\Rightarrow$ α is great β
> where α is a person and β ε {artist, conman, criminal, fraud, general, human being, leader, painter, poet, politician, man, musician, sculptor, woman, writer, ... }

The use of the inference 10.3 resembles that in 6.4, 7.3, and 8.3 insofar as the speak mode applies the inference deductively, going forward from the antecedent to the consequent:

10.4 Deductive use of figurative adnominal inference

α's achievement as β is greater than average $\Rightarrow$ α is great β
$\Uparrow$ *lincoln* — $\Uparrow$ *man* — $\Downarrow$ *lincoln* — $\Downarrow$ *man*

By navigating from the long antecedent to the short consequent, the speaker abbreviates the intended content to a single adnominal modifier.

The hearer, in turn, binds *lincoln* to α and *man* to β in the consequent of the inference 10.2 to go abductively to the antecedent:

10.5 Abductive use of figurative adnominal inference

α's achievement as β is greater than average $\Leftarrow$ α is great β
$\Downarrow$ *lincoln* — $\Downarrow$ *man* — $\Uparrow$ *lincoln* — $\Uparrow$ *man*

As in the other examples of figurative use based on an inference, the derivations apply to only a part of the content, here *great man* in 10.1.

11 Figurative Use of an Adverbial Modifier

A modifier may be used adnominally, as in John drove a fast car with fast modifying car, or adverbially, as in John drove fast with fast modifying drove. Like adnominal modifiers (Sect. 10), adverbial modifiers in figurative or idiomatic use may allow the speaker to be brief, but require the hearer to find the intended literal meaning.

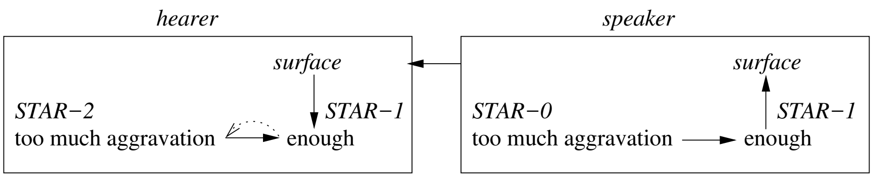
Consider the following example:

11.1 Idiomatic use of enough

Fred had enough.

The idiomatic interpretation may be paraphrased as Fred is not willing to endure any more of a certain nuisance. The nature of the nuisance is left implicit; it is taken for granted that the context of use is sufficient for inferring the nuisance in question. This figurative use is based on a STAR-0 STAR-1 conversion in the speak mode and a STAR-1 STAR-2 conversion in the hear mode:

11.2 Double STAR conversion for figurativ adnominal



The conversion is based on the following inference:

11.3 Inference coding an idiomatic use of have enough

α endure too much of $\beta \Rightarrow \alpha$ have enough
where α is an agent and β ε {aggravation, delay, dirt, dust, idiocy, impertinence, importunity, noise, stupidity, treachery, quarrel, ...}

As in the other figurative uses, the speaker uses the inference deductively, from the antecedent to the consequent.

11.4 Deductive use of figurative adverbial inference

α endure too much of $\beta \Rightarrow \alpha$ have enough
$\Uparrow$ $\Uparrow$ $\Downarrow$
fred *noise* *fred*

The speaker knows the value bound to the variable β in the antecedent, but it does not appear in the consequent.

In the hear mode, the inference is used abductively, from the consequent to the antecedent. A proper interpretation of the antecedent requires the hearer to assign a value to the variable β. It must be selected from the variable restriction in 11.3, based on the utterance situation.

11.5 Abductive use of figurative adverbial inference

α endure too much of β ⟵⟶ α have enough
⇓ ⇑
fred *fred*

The figurative uses described in the Sects. 10 and 11 are idiomatic insofar as their interpretation is conventionalized. There is a gradual transition from the spontaneous production and interpretation of nonliteral uses to the learning of idioms.

12 Surface Compositionality and Polysemy

DBS, like the SLIM theory of language on which it is based, observes the methodological principle of surface compositionality (FoCL, 4.5.1; NLC, 1.6.1; CLaTR, 1.4.3). Surface compositionality depends on the distinction between the meaning_1 of a word (language content type) and its use relative to a context of interpretation, resulting in the speaker meaning_2 of the utterance (language content token).

The distinction avoids misguided assumptions of polysemy. Consider the following examples, which have been presented as "standard cases of polysemy" (Fogal 2016):

12.1 Alleged examples of polysemy

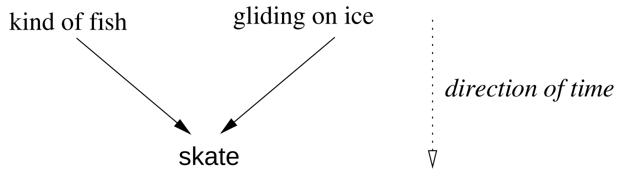
line
I drew a line; She read a line; He has lines around his eyes; Clothes hung on a line; Jorge waited in a line; I made a line of bad decisions.
see
Did you see the sunset?; I see your point; See how it sounds; You should see a doctor; See that you don't break it; Sam's been seeing Maxine.

Instead of contaminating the meaning of, e.g. line and see, by postulating boundless lexical ambiguity with elements of use, a surface compositional DBS analysis makes a clear distinction between (i) the literal meaning_1 of the sign (language content type), and (ii) the speaker meanings_2 (language meaning token) as the use of the sign relative to a context of interpretation. Thereby the literal meaning_1 should be defined as minimal as possible and as precisely as necessary. All that is required of a meaning_1 is the ability *relative to a context of interpretation* to specify the intended referent in the case of nouns and to establish the intended relation in the case of verbs.

Spurious polysemy has the following disadvantages. First, computational inefficiency results from having to pursue six different lexical readings for see and another six for line in parallel, resulting in six times six = 36 readings of John saw a line. Second, each of the alleged meaning distinctions has to be provided with a declarative definition and an operational implementation (grounding) – creating much more work than the goal of (ideally) only one literal meaning_1 per content word in a surface compositional approach.

In lexicography, the term polysemy is explained by contrasting it with homonymy. Synchronically a genuine polysemy and a genuine homonymy are alike in that each consists of a word surface which has more than one literal meaning_1. Diachronically, however, polysemy and homonymy differ in how they evolve. According to classical analysis, homonymy arises when different concepts happen to evolve the same surface, as in the following example:

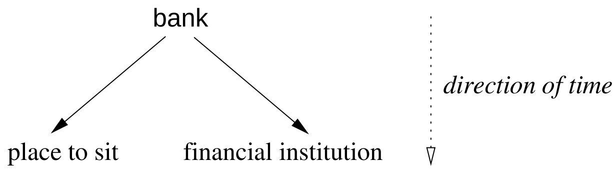
12.2 Evolution of a Homonymy



Other examples are stalk for (i) part of a plant and (ii) harrassing a person, perch for (i) a kind of fish and (ii) a place to roost, and left for (i) the past tense of leave and (ii) the opposite of right.

Polysemy, in contrast, arises when the concept of a given surface, e.g. bank, evolves into different concepts in a process of specialization:

12.3 Evolution of a Polysemy



The origin of this polysemy is the practice of medieval money changers in Italy to display their wares on bench-like pieces of furniture. Other examples are book for (i) something to read and (ii) making a reservation, wood for (i) part of a tree and (ii) a forest, and crane for (i) a bird with a long neck and (ii) equipment for lifting.

Homonymy and polysemy, on the one hand, and the shading of the speaker's utterance $meaning_2$, on the other, have in common that they depend on the current context of interpretation, i.e. resonating content in memory which varies depending on the utterance situation. They differ, however, in that resonating content disambiguates a genuine homonymy or polysemy by *eliminating* one or more of their $meaning_1$ readings. The $meaning_2$ shadings of a sparse literal $meaning_1$, in contrast, are *contributed* by resonating contents.

References

Bandura, A. (1986) *Social Foundations of Thought and Action: A Social Cognitive Theory,* Englewood Cliffs, N.J.: Prentice-Hall

Carpenter, B. (1992) *The Logic of Typed Feature Structures*, Cambridge: CUP

CLaTR = Hausser, R. (2011) *Computational Linguistics and Talking Robots; Processing Content in DBS*, Springer

CTGR = Hausser, R. (2017) "A computational treatment of generalized reference," *Complex Adaptive Systems Modeling*, 5(1):1–26. Also available at http://link.springer.com/article/10.1186/s40294-016-0042-7

Darwin, C. (1859) *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life,* London: John Murray

FoCL = Hausser, R. (1999) *Foundations of Computational Linguistics, Human-Computer Communication in Natural Language, 3rd edition 2014*, Springer

Fogal, D. (2016) "Review of Stephen Finlay's Confusion of Tongues: A Theory of Normative Language," in *Ethics*, Vol. 127

Gallup, G.G. Jr. (1970). "Chimpanzees: Self recognition," *Science* Vol. 167 (3914):86–87

Glucksberg, S. (2001) *Understanding Figurative Language: From Metaphor to Idioms*, Oxford University Press

Hawkins, B.S. (1993) "Peirce and Frege, a question unanswered," *Modern Logic*, Vol. 3.4:376–383

Hobbs, J.R., M.E. Stickel, D. Appelt, and P. Martin (1993) "Interpretation as abduction," *Artif. Intell.* Vol. 63:69–142

NLC = Hausser, R. (2006) *A Computational Model of Natural Language Communication, Interpretation, Inference, and Production in Database Semantics*, Springer

Peirce, C.S. (1903) "Lectures on Pragmatism", CP 5.171

Peirce, C.S. *Collected Papers*. C. Hartshorne and P. Weiss (eds.), Cambridge, MA: Harvard Univ. Press. 1931–1935

Ricoeur, P. (1975) *The Rule of Metaphor: Multi-Disciplinary Studies in the Creation of Meaning in Language*, trans. Robert Czerny with Kathleen McLaughlin and John Costello, S. J., London: Routledge and Kegan Paul 1978. (Toronto: University of Toronto Press 1977)

TCS = Hausser, R. (1992) "Complexity in Left-Associative Grammar," *Theoretical Computer Science*, Elsevier Vol. 106.2:283-308