

Semantic Theory

Week 0 – Introduction

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Information about this course

Contact information:

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Prerequisites:

- This course assumes basic familiarity with first-order predicate logic

*Semesterapparat available at
the Campus-Bibliothek für
Informatik und Mathematik*

Recommended literature:

- Gamut: Logic, Language, and Meaning, Vol. 2, University of Chicago Press, 1991
- Kamp and Reyle: From Discourse to Logic, Kluwer, 1993
- Winter: Elements of Formal Semantics, Edinburgh University Press, 2016
(first three chapters freely available for download: <http://www.phil.uu.nl/~yoad/efs/main.html>)

Exercises & exam

Final exam:

- Your grade for the exam determines your grade for the course
- You have to register before 03.07.2019
- Exam date (provisional): 18.07.2019

Exercise sheets:

- There will be 8 exercise sheets throughout the weeks
- In order to be admitted to the exam, you can miss or fail at most 1 exercise sheet
- Exercises can be done in groups (up to 3 students)

Semantic Theory

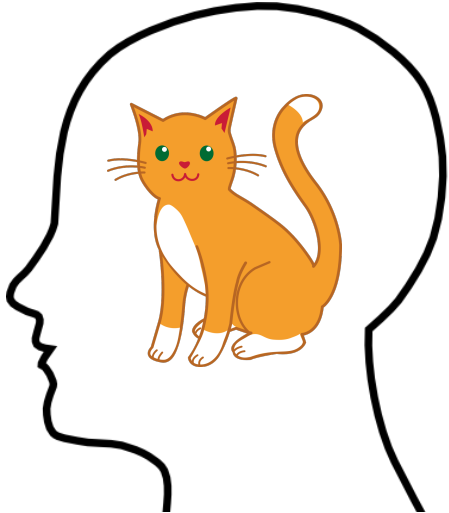
Semantic Theory is the study of (linguistic) meaning

The image shows two overlapping windows. The background window is a dictionary application titled 'Dictionary (589 found)'. The search bar contains 'cat'. The left sidebar lists various cat-related terms, with 'cat' selected. The main content area shows the definition for 'cat' (noun), including its pronunciation [kat], a general definition, and several numbered points: 1. a small domesticated carnivorous mammal with retractile claws; 2. informal, chiefly N. Amer. (especially in the West Coast) a wild animal of the cat family; 3. historical a short tapered stick used for raising an anchor. Below the definition is a 'PHRASES' section with the idiom 'all cats are grey in the dark'. The foreground window is a Google search page for 'cat'. The search bar contains 'cat'. Below the search bar are tabs for 'Web', 'Images', 'Videos', 'News', 'Maps', and 'More'. The 'Images' tab is selected, showing a grid of cat images. The first row of images is categorized into 'Cute', 'And Kittens', 'Clipart', 'Drawing', and 'Cute Baby'. The second row shows five individual cat photos. The third row shows six individual cat photos, including the famous grumpy-looking cat Grumpy Cat.

A philosophical question: What is 'meaning'?

“a small domesticated carnivorous mammal with soft fur, a short snout, and retractile claws”

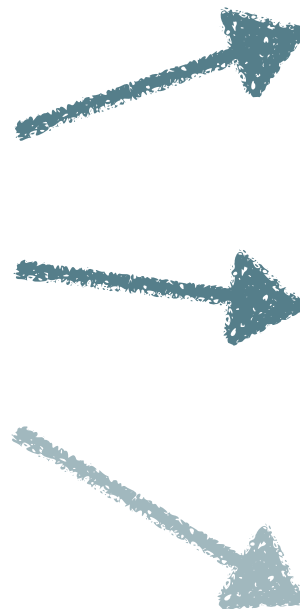
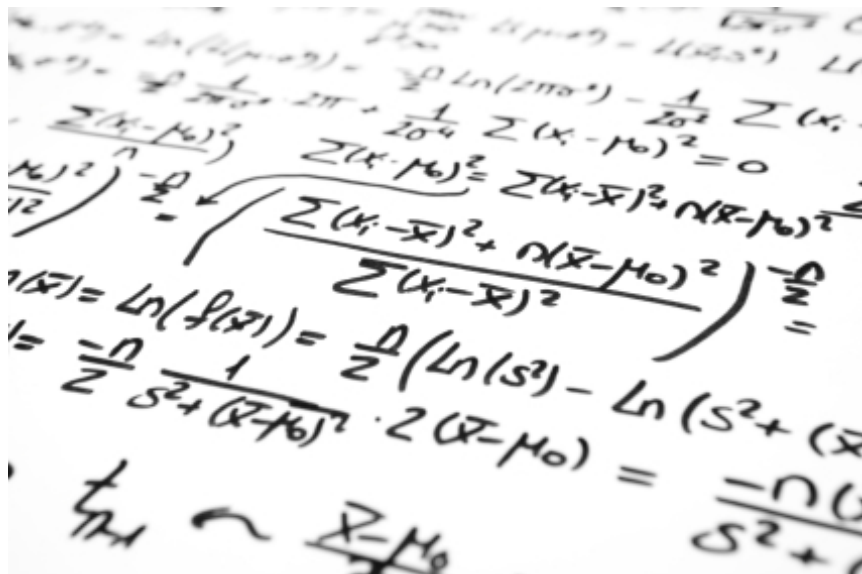
“cat”



Formal semantics

The aim of formal semantics:

Capturing linguistic meaning in a formal (mathematical) system

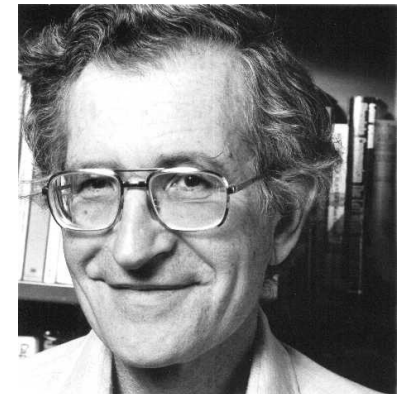


The development of formal semantics

1933 — Bloomfield: “The statement of meanings is [...] the weak point in language-study, and will remain so until human knowledge advances very far beyond its present state.”



1957 — Chomsky: “there is little evidence that ‘intuition about meaning’ is at all useful in the actual investigation of linguistic form”

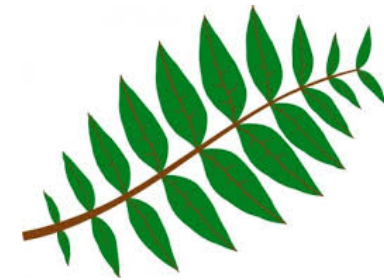


1970 — Montague: “There is in my opinion no important theoretical difference between natural languages and the artificial languages of logicians”



Course Overview

- Part I: Sentence semantics (compositional semantics)
- Part II: Lexical semantics
- Part III: Discourse semantics
- Part IV: Current issues in Semantic Theory



Part I: Sentence semantics



A basic semantic principle

"For two sentences A and B , if in some possible situation A is true and B is false, A and B must have different meanings."

(M. Cresswell, 1975)

Applied to logical representations:

- For a logical formula α and a sentence A : If in some possible situation corresponding to a model structure M , sentence A is true, and α is not, or vice versa, then α is not an appropriate meaning representation for A .

Sentence meaning

Truth-conditional semantics:

to know the meaning of a (declarative) sentence is to know what the world would have to be like for the sentence to be true:

Sentence meaning = truth-conditions

Indirect interpretation:

1. Translate sentences into logical formulas:

Every student works $\mapsto \forall x(\text{student}'(x) \rightarrow \text{work}'(x))$

2. Interpret these formulas in a logical model:

$\llbracket \forall x(\text{student}'(x) \rightarrow \text{work}'(x)) \rrbracket^{M,g} = 1$ iff $V_M(\text{student}') \subseteq V_M(\text{work}')$

Step 1: from sentence to formula

Propositional logic: Propositions as basic atoms

Syntax: propositions (p, q, \dots), logical connectives ($\neg, \wedge, \vee, \rightarrow, \leftrightarrow$)

Semantics: truth tables — truth conditions, entailment

p	q	$p \& q$	$p \vee q$	$p \rightarrow q$	$p \leftrightarrow q$
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

Predicate logic: Predicates and arguments

Syntax: predicates & terms (love'(j', m'), mortal'(x), ...), quantifiers ($\forall x \phi, \exists x \phi$), logical connectives ($\wedge, \vee, \neg, \rightarrow, \leftrightarrow$)

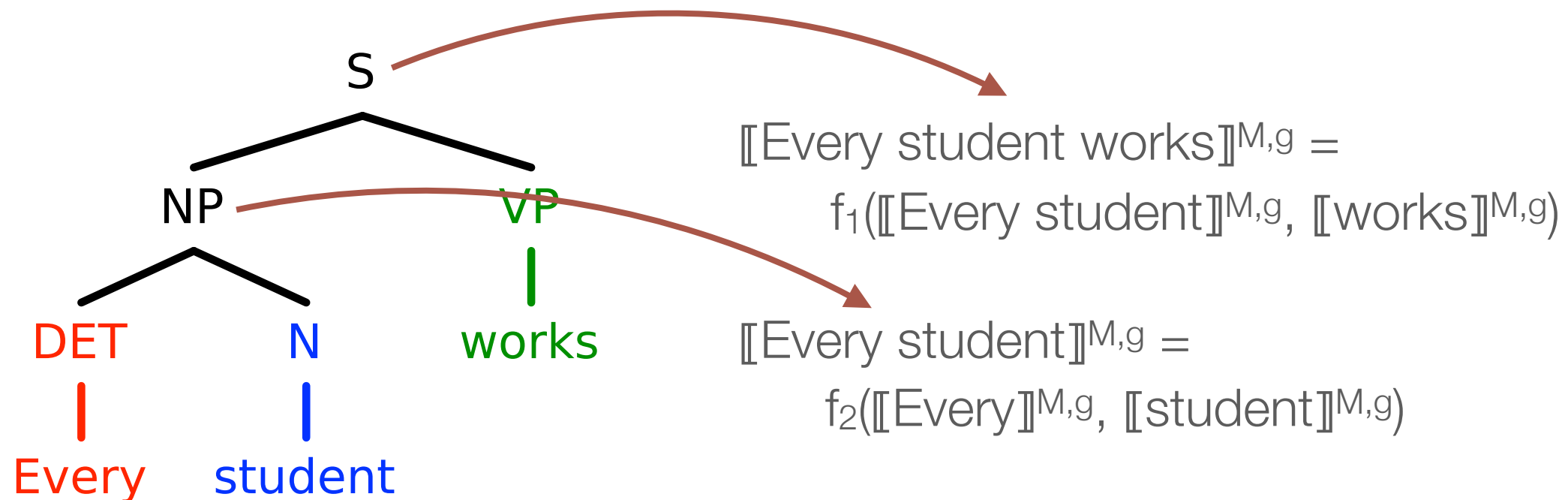
Semantics: model structures and variable assignments

Compositionality

The principle of compositionality:

The meaning of a complex expression is a function of the meanings of its parts and of the syntactic rules by which they are combined (Partee et al., 1993)

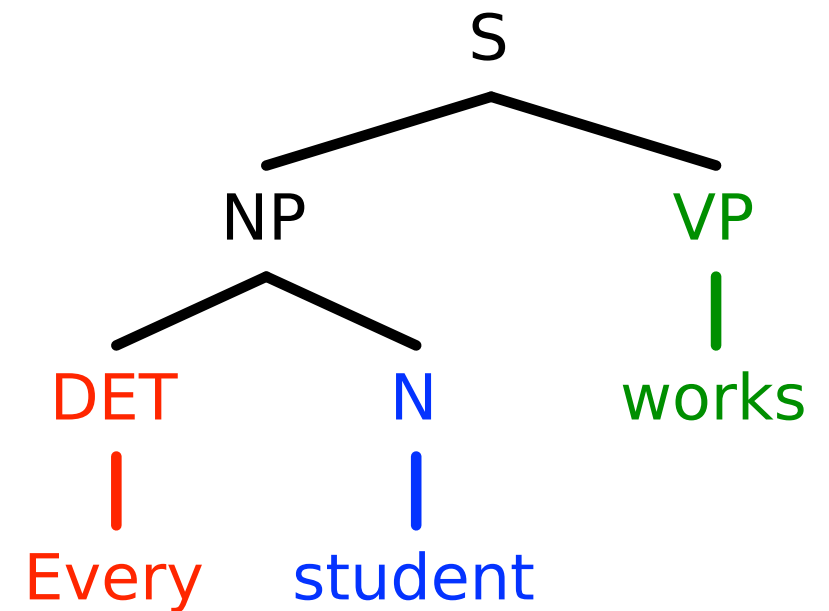
- *Every student works*



Compositional Semantics Construction

Semantic lexicon:

- every $\mapsto \lambda P \lambda Q \forall x (P(x) \rightarrow Q(x))$
- student $\mapsto \text{student}'$
- works $\mapsto \text{work}'$



Semantics construction:

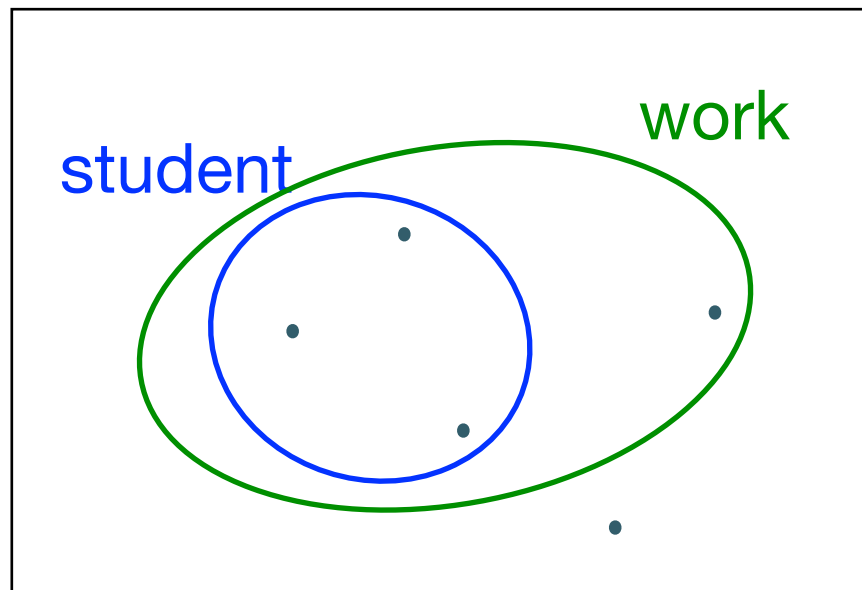
- $\lambda P \lambda Q \forall x (P(x) \rightarrow Q(x))(\text{student}') \Rightarrow_{\beta} \lambda Q \forall x (\text{student}'(x) \rightarrow Q(x))$
- $\lambda Q \forall x (\text{student}'(x) \rightarrow Q(x))(\text{work}') \Rightarrow_{\beta} \forall x (\text{student}'(x) \rightarrow \text{work}'(x))$

Step 2: from formula to model

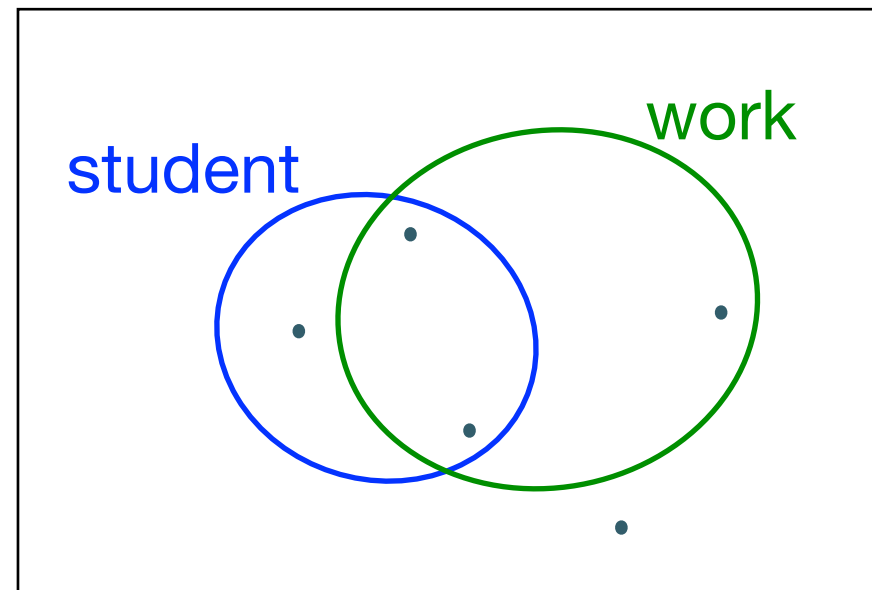
Every student works

$\llbracket \forall x(\text{student}'(x) \rightarrow \text{work}'(x)) \rrbracket^{M,g} = 1$ iff $V_M(\text{student}') \subseteq V_M(\text{work}')$

M1:



M2:



Issues for sentence semantics

Quantifier scope

1. An American flag was hanging in front of every building
2. Every student speaks two foreign languages
3. A representative of every company saw most samples

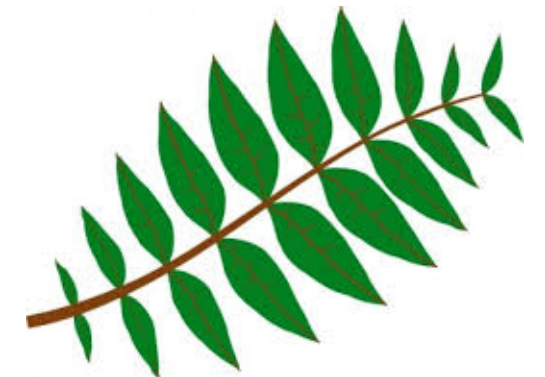
Interpretation of adjectives

4. a. Jumbo is a grey elephant \mapsto Jumbo is grey
b. Jumbo is a small elephant $\not\mapsto$ Jumbo is small

Monotonicity and generalised quantifiers

5. All children came home late \mapsto All children came home
6. No children came home late $\not\mapsto$ No children came home

Part II:
Lexical semantics



Zooming in: the meaning of words

Lexical semantics revisited:

- student \mapsto **student'** ... what does the ' stand for?



Structured approaches to the lexicon:

Lexical meaning as relations between concepts in a model

- a “student” is someone who studies
- a “bachelor” is a man who is not married

Issues for lexical semantics

Event-denoting expressions

1. a. Bill saw an elephant.
b. Bill saw an accident.
c. Bill saw the children play.

Verb alternatives and semantic roles

2. a. The window broke.
b. A rock broke the window.
c. John broke the window with a rock.

Plurals and collective predicates

3. Bill and Mary met \neq Bill met
4. Five students carried three pianos upstairs.

Part III: Discourse semantics



Beyond the sentence boundary

Limitations of sentence-level semantics:

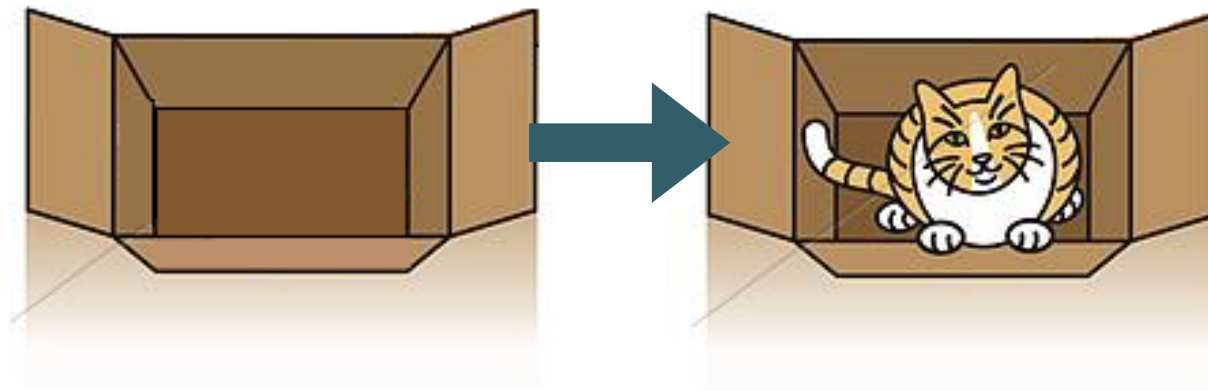
- Anaphora
 1. John hit Bill. He hit him back.
 2. If a farmer owns a donkey, he feeds it.
- Presuppositions
 3. a. Bill regrets that his cat has died.
b. Bill doesn't regret that his cat has died
- Discourse relations
 4. John fell. Mary helped him up.
 5. John fell. Mary pushed him.

Dynamic Semantics

Revisiting the idea of meaning as truth-conditions

- There is more to meaning than truth-conditions
- Meaning is context-dependent
- Meaning is dynamic: it keeps changing

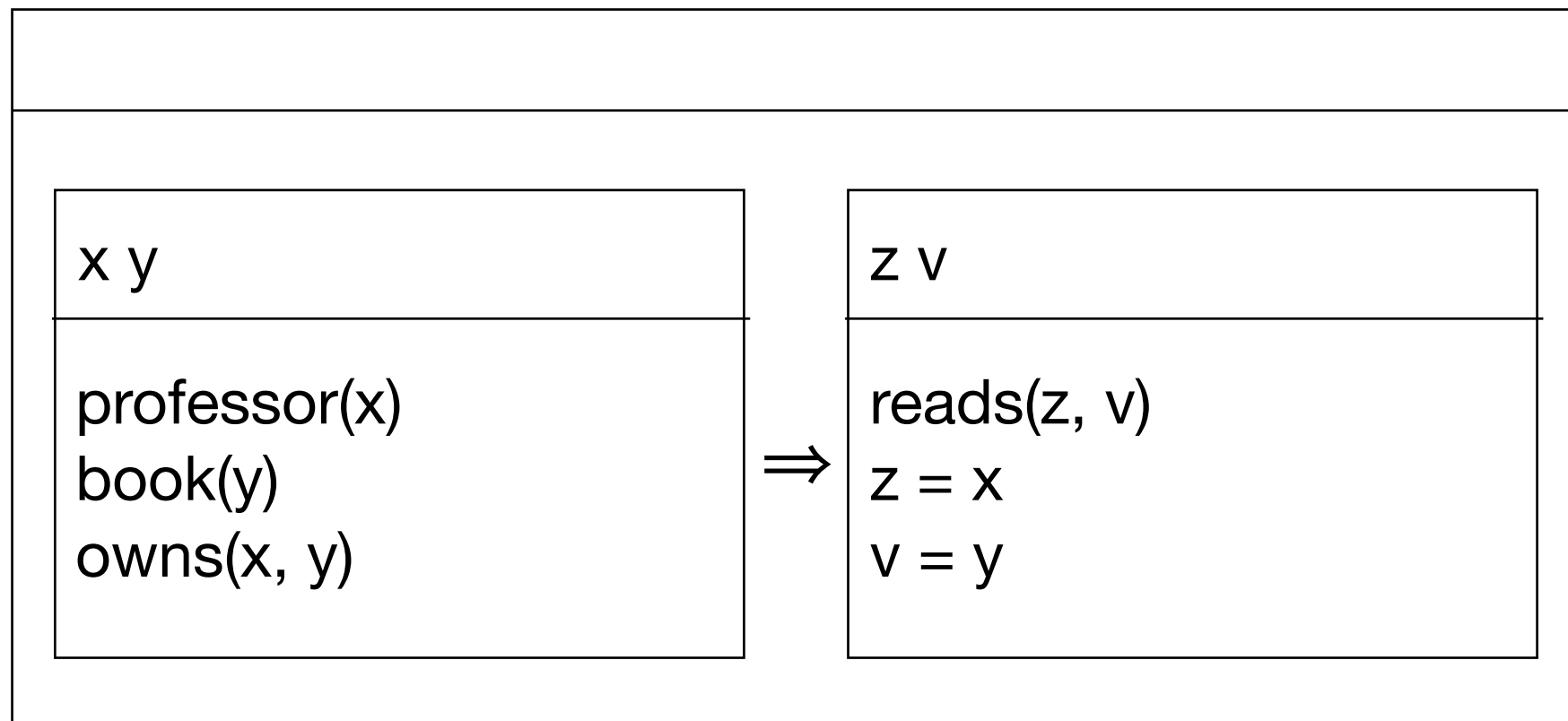
Solution: Meaning = context-change potential



Discourse Representation Theory

If a professor owns a book, he reads it.

- $\forall x \forall y [\text{professor}(x) \wedge \text{book}(y) \wedge \text{own}(x,y) \rightarrow \text{read}(x,y)]$



Applications of DRT

The image shows a web browser window displaying a document viewer interface. The browser address bar shows `gmb.let.rug.nl`. The page title is "Document 88/0480 - GMB Explorer". The interface includes a navigation menu with links like "explore", "challenges", "semantic lexicon", "search", "news feed", "statistics", "warnings", and "users". A user greeting "Welcome, noortje (Master Annotator)" is visible. The document viewer shows "Document 481 of 10102, ID: 88 / 0480" and a status of "accepted". Below this, there are tabs for "metadata", "raw", "tokens", "sentences", "discourse", "8 bits of wisdom", and "0 warnings". The main content area displays several columns of text, each representing a different discourse structure (k1, k2, k3, k4, k5) with associated semantic information and relations.

Overlaid on the right side of the browser window is a smaller window titled "PDRT - ghc - 114x39". This window contains a terminal-like interface for a Prolog-style language. The prompt is `Prelude Data.DRS>`. The user has entered a query: `DRS [DRSRef "x"] [Rel (DRSRel "Luke") [DRSRef "x"]]`. The system returns information about the query: "size: 3 sentences, 76 tokens", "last processed: 14 April 2015, 17:16:53", and "C&C tools/processor: 2554". Below this, there are buttons for "Update to...", "Reprocess document", and "report issue". The terminal also shows a search filter interface with options for "Filter by part:", "Filter by status:" (set to "accepted"), "Filter by subcorpus:", and "Warnings:". A search button is visible. The terminal output shows a list of relations: `father(y) of(x,y)` and `like(x,y)`. Below the terminal, there is a diagram illustrating the composition of relations: `Luke(x) + father(y) of(x,y) = Luke(x) father(y) of(x,y)`. The diagram shows a box labeled "Luke(x)" on the left, a plus sign, a box labeled "father(y) of(x,y)" in the middle, an equals sign, and a box labeled "Luke(x) father(y) of(x,y)" on the right. Below this, there is another diagram showing a box labeled "like(x,y)" in the middle, with "Luke(x)" and "father(y) of(x,y)" boxes on either side, suggesting a composition or decomposition of the "like" relation.



Part IV: Current Issues in Semantic Theory



The Next Big Thing in Semantic Theory...

“You shall know a word by the company it keeps” (J. R. Firth, 1957)

Distributional Semantics

- word meaning as high dimensional vectors derived from corpora (*big data!*)
- semantic similarity ~ vector similarity
- ... but what about formal semantic principles such as compositionality?

Distributional Formal Semantics

- Meaning vectors defined over propositions in a world
- Expressive, compositional, probabilistic, inferential and neurally plausible
- ... but how does it relate to formal semantic models?

Open questions

- Where is the border between semantics and pragmatics?
- What do (or: can) formal semantic theories say about the way meaning is stored and created in the human brain?
- How can we use formal semantics for practical purposes (for example to improve machine translation)?

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