

Semantic Theory

Introduction

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Information about this course

Communication:

- Course website: <http://njvenhuizen.github.io/teaching/ST21/index.html>
- Email: noortjev@coli.uni-saarland.de / brouwer@coli.uni-saarland.de
- Main communication platform: Microsoft Teams (slides, exercises, lectures, chat)

Prerequisites:

- Familiarity with first-order predicate logic. See: Logic in Action, Chapter 4 (Sections 4.1 & 4.2).

Recommended literature / online resources:

- Logic in Action (Ch. 4), J. van Benthem, H. van Ditmarsch, J. van Eijck and J. Jaspars, 2016. <http://logicinaction.org/docs/ch4.pdf>
- Elements of Formal Semantics (Ch. 1-3), Yoad Winter, Edinburgh University Press, 2016. <https://www.phil.uu.nl/~yoad/efs/main.html>
- Stanford Encyclopedia of Philosophy, Edward N. Zalta (principal editor). <https://plato.stanford.edu/>

Course format

Online lectures

- Please turn on your video (!)
- Strong focus on self-study
- Interactive, Q&A style lectures and exercise sessions

Exam and Exercises

- Final exam date (provisional): 22.07.2021
- Your grade for the final exam will be your grade for the course
- There will be 8 exercises throughout the semester; to be admitted to the exam, you may skip or fail at most one weekly exercise

Semantic Theory

Semantic Theory is the study of (linguistic) meaning

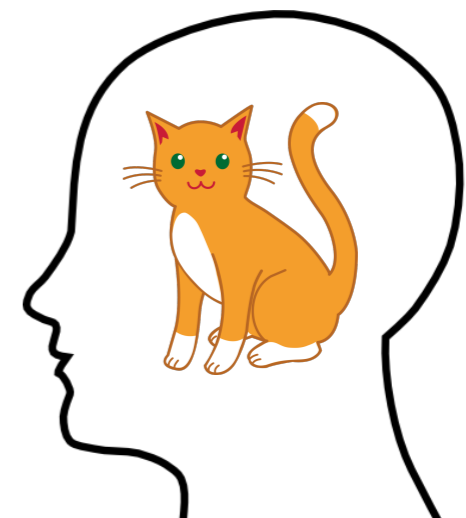
The image displays two overlapping windows. The background window is a dictionary application titled 'Dictionary (589 found)'. The search bar contains 'cat'. The left sidebar lists various 'cat-' related terms. The main content area shows the definition for 'cat' (noun), including its pronunciation [kat], a general definition, and a list of related terms and phrases. The foreground window is a Google search results page for 'cat'. It shows the search bar with 'cat', navigation tabs for 'Web', 'Images', 'Videos', 'News', and 'Maps', and a grid of image results. The image results are categorized into 'Cute', 'And Kittens', 'Clipart', 'Drawing', and 'Cute Baby'. The 'Cute' category shows a tabby cat lying down. The 'And Kittens' category shows a ginger kitten. The 'Clipart' category shows a cartoon orange cat. The 'Drawing' category shows a line drawing of a cat. The 'Cute Baby' category shows a small kitten. Below these categories, there are two rows of individual cat images, including a tabby, a ginger, a grey, and a Siamese cat.

A philosophical question: What is 'meaning'?

“cat”



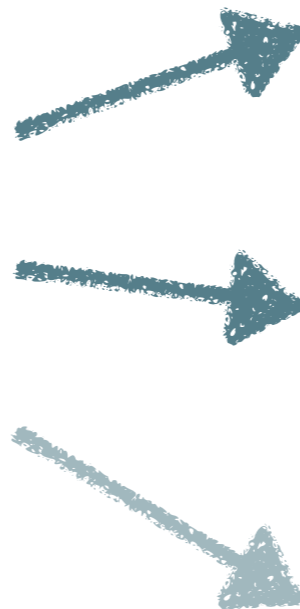
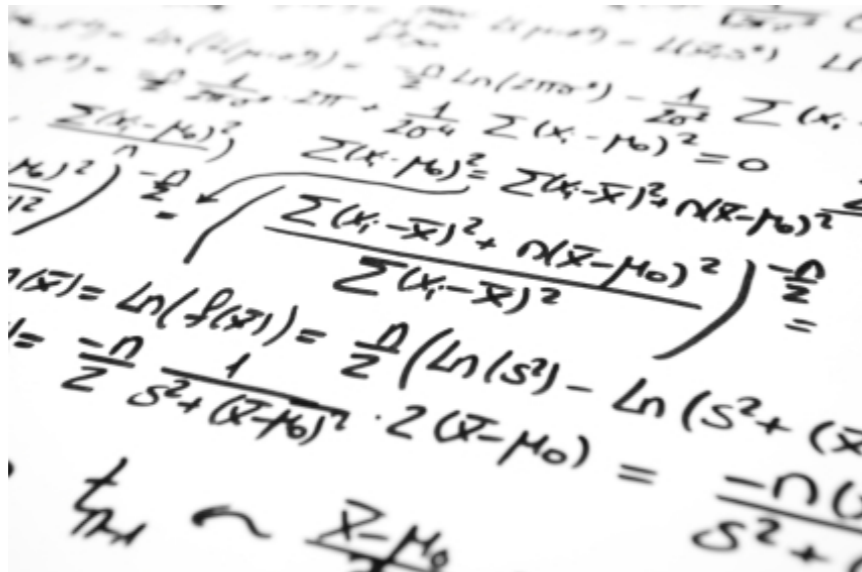
“a small domesticated carnivorous mammal with soft fur, a short snout, and retractile claws”



Formal semantics

The aim of **formal** semantics:

To explain how meaning derives from linguistic **form**, in terms of mathematical **formal** principles

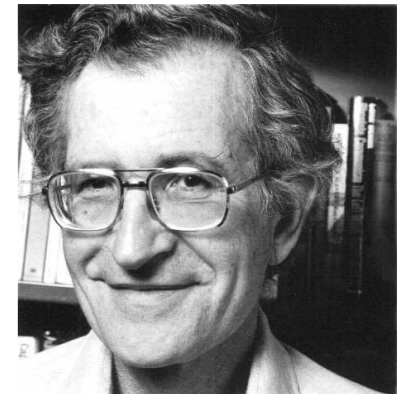


The development of formal semantics

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”

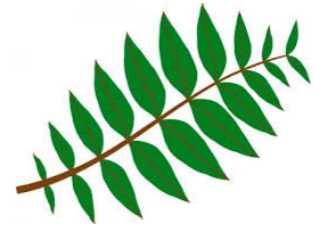


1970 — Montague: “There is in my opinion no important theoretical difference between natural languages and the artificial languages of logicians”



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 ($\wedge, \vee, \neg, \rightarrow, \leftrightarrow$)

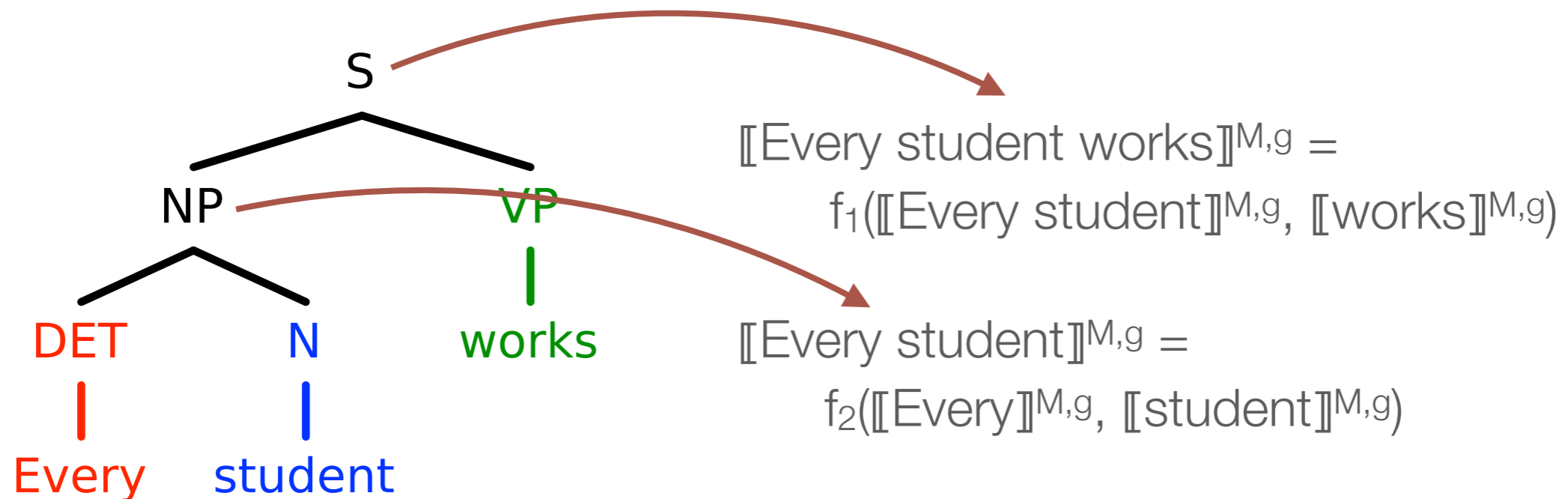
Semantics: model structures and variable assignments

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)

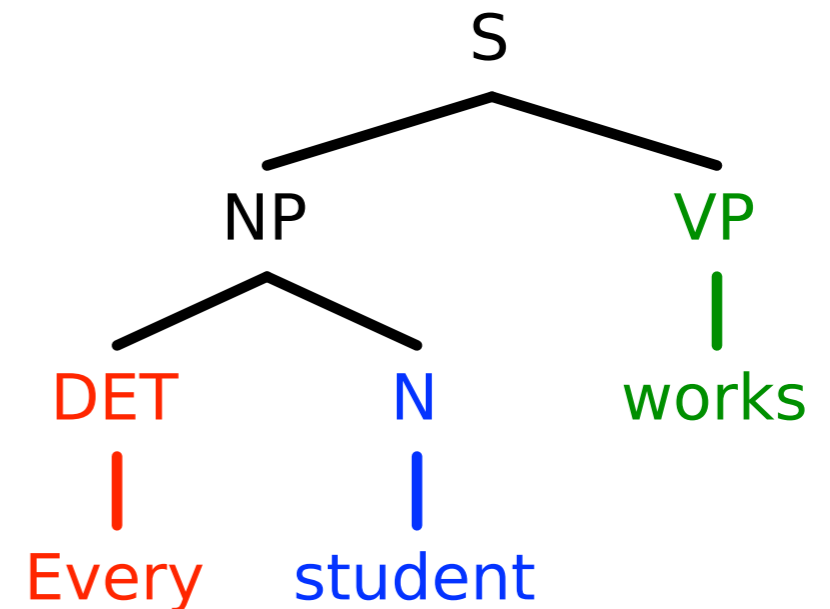
- *Every student works*



Compositional Semantics Construction

Semantic lexicon:

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



Semantics construction:

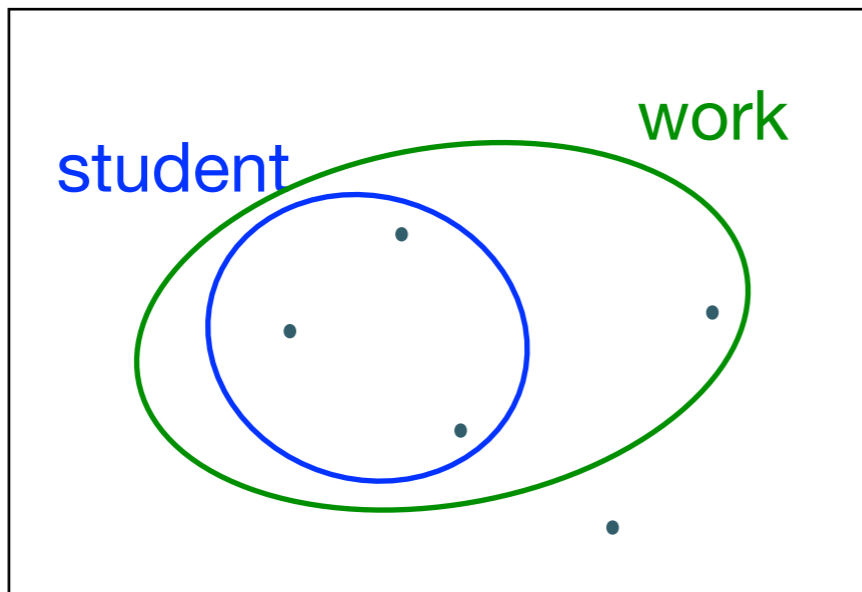
- $\lambda P \lambda Q \forall x (P(x) \rightarrow Q(x))(\text{student}')$ \Rightarrow_{β} $\lambda Q \forall x (\text{student}'(x) \rightarrow Q(x))$
- $\lambda Q \forall x (\text{student}'(x) \rightarrow Q(x))(\text{work}')$ \Rightarrow_{β} $\forall x (\text{student}'(x) \rightarrow \text{work}'(x))$

Step 2: from formula to model

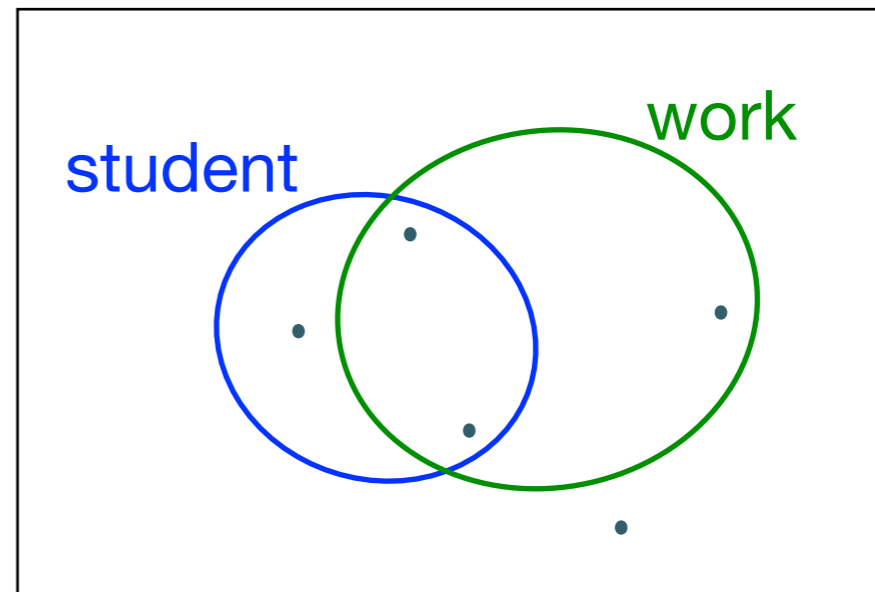
Every student works

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

M1:



M2:



Topics in 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

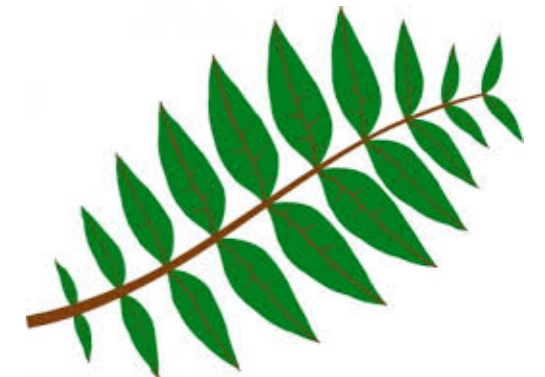
Interpretation of adjectives

4. a. Jumbo is a grey elephant \rightarrow Jumbo is grey
b. Jumbo is a small elephant \nrightarrow Jumbo is small

Monotonicity and generalised quantifiers

5. All children came home late \rightarrow All children came home
6. No children came home late \nrightarrow 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

Topics in 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:

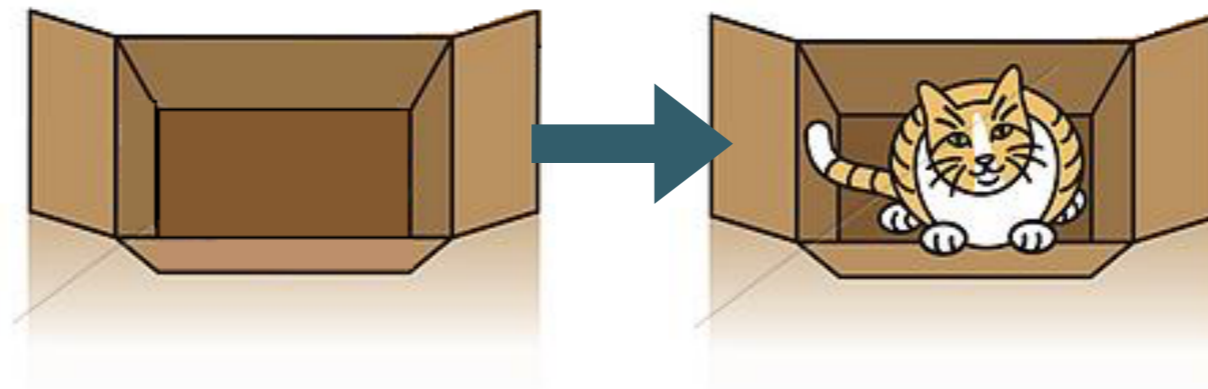
- Anaphora
 1. John hit Bill. He hit him back.
 2. If a farmer owns a donkey, he feeds it.
- Presuppositions
 3. a. Bill regrets that his cat has died.
b. Bill doesn't regret that his cat has died
- Discourse relations
 4. John fell. Mary helped him up.
 5. John fell. Mary pushed him.

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

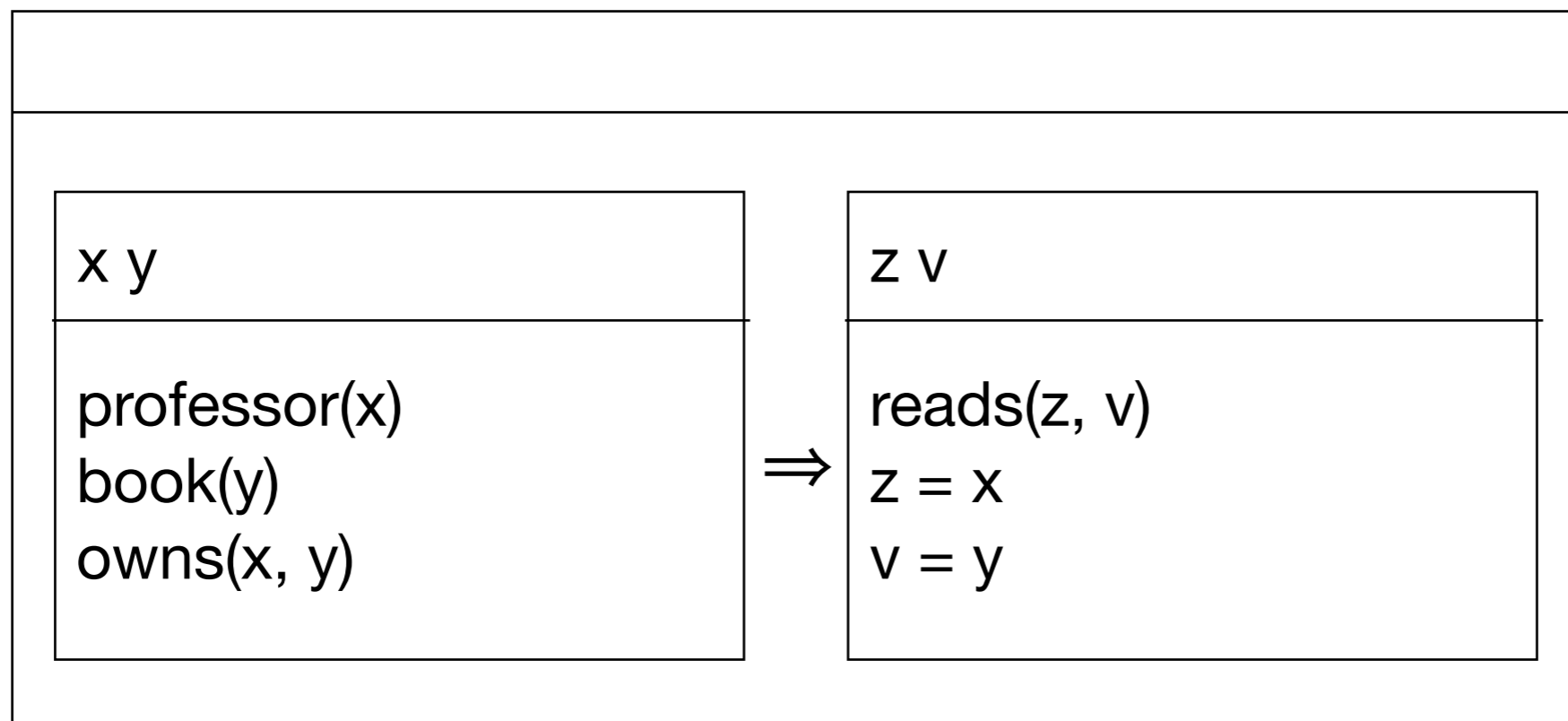
Solution: Meaning = context-change potential



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 header includes the Groningen Meaning Bank logo and navigation links: `explore`, `challenges`, `semantic lexicon`, `search`, `news feed`, `statistics`, `warnings`, `users`. A welcome message for `noortje` (Master Annotator) is visible, along with `logout` and `change password` links.

The document viewer shows "Document 481 of 10102, ID: 88 / 0480". It includes navigation controls like `< first`, `<< previous`, `next >>`, `last >`, and `random`. The status is `accepted` with a `history` link. There is a "Change to:" dropdown set to `accepted` and a "Comment:" input field with a `Submit` button.

At the bottom, there are tabs for `metadata`, `raw`, `tokens`, `sentences`, `discourse`, `8 bits of wisdom`, and `0 warnings`.

Below the document viewer, there are several panels showing semantic information:

- k1:** `x1 e1 t1 x2 t2 x3 x4 x5 x6`
`people(x1)`
`touch(e1)`
`Experiencer(e1, x1)`
`now(t1)`
`x2 = t1`
`t2 > x2`
`e1 > t2`
`lx3l = 31`
`x4 < x3`
`x5 < x3`
`city(x4)`
`town(x5)`
`named(x6, america, geo)`
`across(x3, x6)`
`in(e1, x3)`
- k2:** `x7 e2`
`people(x7)`
`ride(e2)`
`Agent(e2, x7)`
`x8` `t3 x9 t4 x10 x11 x12 x13`
`thing(x8)`
`x14 x15 x16 e3 t1 t5`
`thing(x14)`
`car(x15)`
`future(x16)`
`of(x15, x16)`
`call(e3)`
`Agent(e3, x14)`
`Result(e3, x15)`
`Theme(e3, x8)`
`now(t1)`
`e3 < t5`
`t1 < t5`
`in(e2, x8)`
`even(e2)`
`now(t3)`
`x9 = t3`
`t4 > x9`
`e2 > t4`
`lx10l = 31`
`x11 < x10`
`x12 < x10`
`city(x11)`
`town(x12)`
`named(x13, america, geo)`
- k3:** `x17 x18 x19 x20 x21 x22 x23 x24 x25 x26 e1 s2 e4 x27 t1 x28 e5`
`named(x17, u.s.-departments, org)`
`named(x19, energy, org)`
`x19 < x18`
`named(x20, transportation, org)`
`x20 < x18`
`of(x17, x18)`
`named(x21, california-fuel-cell-partnership, org)`
`named(x23, national-hydrogen-association, org)`
`x23 < x22`
`lx24l = 9`
`auto(x25)`
`of(x24, x25)`
`manufacturer(x24)`
`x24 < x22`
`rel(x21, x22)`
`rel(x17, x21)`
`Experiencer(s1, x26)`
`several(s1)`
`Experiencer(s2, x26)`
`hydrogen-fueled(s2)`
`car(x26)`
`put(e4)`
`Agent(e4, x17)`
`Theme(e4, x26)`
`tour(x27)`
`on(e4, x27)`
`now(t1)`
`x28 = t1`
`e5 > x28`
`e4 > e5`
- k4:** `x29 x30 x31 e6 t1 t6 x32 x33`
`named(x29, voa, org)`
`of(x30, x29)`
`named(x30, paul, per)`
`named(x30, sisco, per)`
`named(x31, dc, geo)`
`catch(e6)`
`Agent(e6, x30)`
- k5:** `x34 x30 x35 e7 t1 t7`
`named(x34, voa, org)`
`of(x30, x34)`
`named(x30, paul, per)`
`named(x30, sisco, per)`
`report(x35)`
`file(e7)`
`Agent(e7, x30)`
`now(t1)`
`e7 < t7`

The PDRT sandbox window shows a terminal with the following content:

```
Prelude Data.DRS> DRS [DRSRef "x"] [Rel (DRSRel "Luke") [DRSRef "x"]]  
size: 3 sentences, 76 tokens  
last processed: 14 April 2015, 17:16:53  
C&C tools/processor: 2554  
Update tools/processor: report issue  
Filter by part: [dropdown]  
Filter by status: accepted [dropdown]  
Filter by subcorpus: [dropdown]  
Warnings: [dropdown]  
Prelude Data.DRS> DRS [DRSRef "y"] [Rel (DRSRel "father") [DRSRef "y"], Rel (DRSRel "of") [DRSRef "x", DRSRef "y"], Neg (DRS [] [Rel (DRSRel "like") [DRSRef "x", DRSRef "y"]])] [search]  
y  
father(y)  
of(x,y)  
like(x,y)  
Prelude Data.DRS> printMerge luke doesntlikehisfather  
x y  
Luke(x) + father(y) of(x,y) = Luke(x) father(y) of(x,y)  
like(x,y) like(x,y)
```

PDRT
SANDBOX

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

- lexical meaning: 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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