Sentence Semantics

General Linguistics

Jennifer Spenader, February 2006

(Most slides: Petra Hendriks)

Data to be analyzed

(1) Maria slaapt.

(2) Jan slaapt.

(3) Maria slaapt en Jan slaapt.

(4) Iedereen slaapt.

(5) Maria doet iets wat Jan doet.

- We need a way to unambiguously represent natural language meaning
- The representations should allow inferences like those made by speakers, e.g. if (3) is true then (1) and (2) should follow from it.

Prerequisites for a good semantic theory

A good semantic theory must:

- Be formally defined
- Be able to explain how the meaning of a larger sentences or expression is built from smaller units of meaning
  - see regularities in meaning
- Explain why certain meaning relations hold between words and sentences

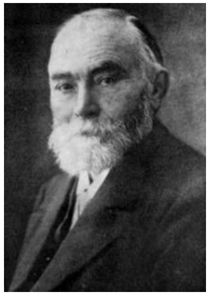
Advantages of formal definitions

- Possible to make precise predictions that can be tested
- Possible to implement the theory in a computer system, which by doing so different applications are possible where meaning plays an integral role, e.g. search engines, natural language interfaces, etc.

Compositionality

- Language is recursive
- Meaning can therefore not be modeled with a finite list of all sentences and their corresponding meanings
- Algorithms for determing meaning or therefore necessary

➔Principal of compositionality



Principle of Compositionality

The meaning of a complex expression is a function of the meaning of its parts in the way in which they are combined

Manner of combining:

syntactic structure

Sentence meaning

The meaning of a sentences is dependent on the meaning of the words it contains:

(1) Marie ziet Jan.

(2) Marie hoort Jan.

But the meaning is also determined by the way in which the words are combined:

(1) Marie ziet Jan.

(2) Jan ziet Marie.

Problems with compositionality

- Idioms: *een blauwtje lopen, boter op het hoofd hebben*
- Figurative language, o.a. metaforen en ironie: *de avond valt, het schip der woestijn*
- Anaphors: *zichzelf, hem, het*
- Context-dependent meaning (esp. deixis): *gisteren, hier, ik*
- Mismatches between syntactic structure and semantic structure

Propositional logic as a representation for natural language?

- Sentences describe situations
- Synonymous sentences describe the same situations, i.e they express the same proposition
- Ambiguous sentences express different propositions
- Propositions describe a situation which can be true or false
- The meaning of a compound sentence can be characterized with the help of propositional logic

Propositional logic

- In propositional logic propositions are represented with letters (p,q, …).
- Propositions are associated with a truth value: 1 (true) of 0 (false).
- The truth value from a sentence can be determined using a truth-value table:
  - Tautologies: sentences that are always true
  - Contradictions: sentences that are always false
  - Contingent: sentences that are true in some situations and false in others

Truth value table 1

Het regent	of	de zon schijnt
p	$\vee$	q
1	1	1
1	1	0
0	1	1
0	0	0

➔ sometimes true, sometimes false: contingent

Truth value table 2

Het regent	of	het regent niet
p	$\vee$	$\neg$ p
1	1	0
0	1	1

➔ Always true: a tautology

Truth value table 3

Het regent	en	het regent niet
p	$\wedge$	$\neg$ p
1	0	0
0	0	1

➔ Always false: a contradiction

Truth values

- What do you know, if you know that “Maria slaapt” is true?
  - After fixing the time and place (and which Maria!) the truth or falsity will tell you something about the “condition” or “situation” in which the world is in,.
  - Actually, it says more about the world than about the meaning of a sentence
  - It is more important to know under what conditions the sentence will be true or false: **truth conditions**

Truth conditions

- The goal of formal semantics:
  - determine the truth conditions of sentences
- From truth-conditions to truth values
  - the truth-values of a sentence can then be calculated by evaluating truth conditions with respect to a specific situation
  - in propositional logic the "situation" is the valuation that holds

Limits of propositional logic

(1) Maria slaapt. → P
(2) Jan slaapt. → Q
(3) Maria slaapt en Jan slaapt. → P & Q
(4) Iedereen slaapt. → R

- propositional logic **can** represent semantics of compound sentences
- But: it **ignores the internal semantic structure of sentences!**
- **it also ignores quantification**

- **Propositional logic is not a good representation for natural language**

Predication logic for NL semantics?

Expressions in natural language	*Translation in predicate logic*
Proper names	Individual constants a, b, c
Intransitive verbs, adjectives, adverbs, and nouns	One-place predicate constants P, Q
(Di-)transitive verbs	Two/Three place predicate constants P, Q
Negation, conjunction, disjunction and implication	Connectives $\neg$, $\wedge$, $\vee$, $\rightarrow$

Predicate logic without quantification

(1) Maria slaapt. → S(m)
(2) Jan slaapt. → S(j)
(3) Maria slaapt en Jan slaapt. S(m) & S(j)

S(m) & S(j) |- S(m)

-Now we can see that Maria and Jan have something in common

(though we could have drawn this particular conclusions also in propositional logic)

Predicate logic with quantification

Quantificational expressions:

every student, no one, no child (geen kind)

- Can e

- Variables x, y
- Quantifiers: ∃ (existential quantifier) and ∀ (universal quantifier)

Variables must be bound. This is done via quantifiers

Quantificational Expressions

Quantification expressions are formed in two steps:

2. The construction of an open proposition.

   Example: *S(x)*: x is sterfelijk

   K(x,y): x kust y

5. Closing off an open proposition

   Example: $\forall x$ *[S(x)]*: iedereen is sterfelijk

   $\forall x \exists y$ *[K(x,y)]*: iedereen kust iemand

   $\exists x \forall y$ *[K(x,y)]*: iemand kust iedereen

Interpretation

- Methods in formal semantics:

  Sentence ➔ Translation into formal language
  ➔ Interpretation via automatic interpretation procedure from the formal language

- Predicate logic has an automatic interpretation procedure
  - Interpretation with respect to a model

➔ Model-theoretic semantics

Interpretation in predicate logic

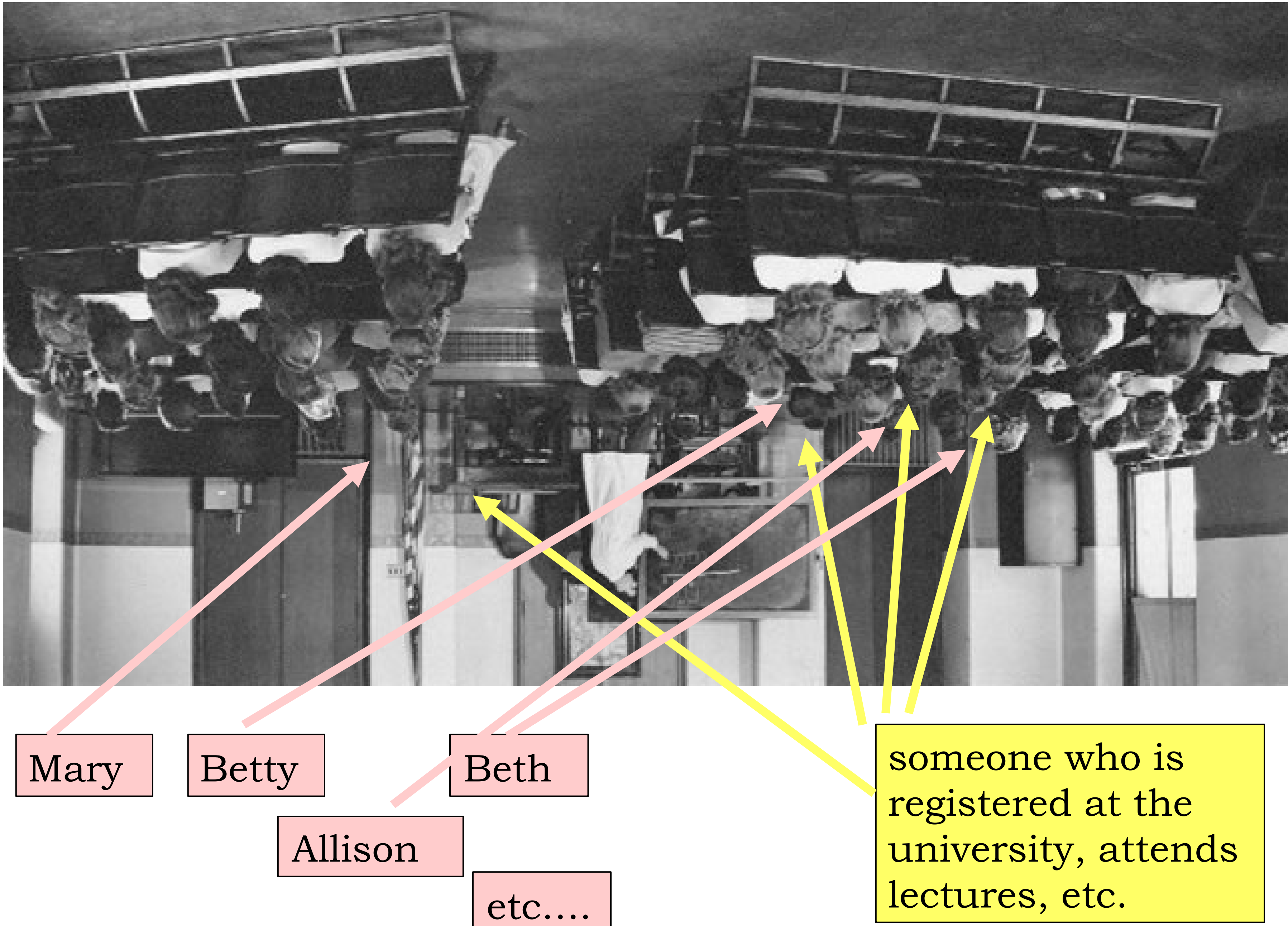
- Model M is made out of:
  - domain E, interpretation function I, and an assignment function g
- Proper nouns:
  - For every proper name, the interpretation function I returns an individual in the domain E
- Predicates:
  - Interpretation function I returns a set of individuals in domain E for every one-place predicate constant, and for n+-predicate constants returns an ordered n-tuple from individuals in the domain E
- Variables:
  - The assignment function g assigns each varible to all possible values in E

Proper names

- Proper names are called *rigid designators* (starre verwijzers).
- They always refer to 1 individual in the domain (I is an interpretation **function!**)
- Example:the proper name *Beatrix* always refers to the individual Beatrix, just as the expressions *de koningin van Nederland does*
- The expression *de koningin van Nederland* is a predicate that has different values depending on the context

Predicates

- Predicate refer to characteristics of individuals
- For example: the predicate *zingen* refers to the set of individuals that sing; the predicate *student* refers to all individuals that are students
- Predicates are expression with several syntactic categories: $V_{intrans}$, A, Adv, N.


Mary
Betty
Beth
Allison
etc….
someone who is registered at the university, attends lectures, etc.

Intensional vs. extensional

Two ways in which to describe characteristics:
- **Intensional:**
  - A student is someone who is registered at a university, attends lectures, etc.
- **Extensional:**
  - Students are Mary, Allison, Betty, etc.

Model-theoretic semantics uses an extensional description of characteristics

Characteristic P = a collection of individuals with that all share characteristic P
- Problem: being a talking elephant and being a unicorn are the same thing in an extensional theory

Scope ambiguity

Semantic ambiguity can be represented by having different translations:

- Iedere student spreekt een vreemde taal.

  $\forall x[Student(x) \rightarrow \exists y[Vreemde\text{-}taal(y) \wedge Spreken(x,y)]]$

  $\exists y[Vreemde\text{-}taal(y) \wedge \forall x[Student(x) \rightarrow Spreken(x,y)]]$

Scope ambiguity (Bereiksambiguïteit): the universal quantifier has scope over the existential quantifier, or the other way around.

Scope ambiguity

Negation can also lead to scope ambiguities in combination with universal and existential quantifiers:

- Darcy wil niet dansen met alle meisjes.
  1. $\forall x[Meisje(x) \rightarrow \neg [Darcy\text{-}wil\text{-}dansen\text{-}met(x)]]$
  2. $\neg \forall x[Meisje(x) \rightarrow [Darcy\text{-}wil\text{-}dansen\text{-}met(x)]]$

Limits of first-order predicate logic

(1) Maria slaapt.
(2) Jan slaapt.
(3) Maria slaapt en Jan slaapt.
(4) Iedereen slaapt.
(5) Maria doet iets wat Jan doet.

- In first order predicate logic there are no predicate variables
  - for this reason it is impossible to quantify over predicates, or to allow predicates to take other predicates as arguments
- But natural language allows this!

More predicate variables

Quantification over predicates is possible in natural language:

(2) Marie doet iets wat Jan doet

This is not well-formed in 1^{st} order predicate logic: $\exists P\ [P(m)\ \&\ P(j)]$ *???*

Predicating predicates is possible in natural language:

1. Zwemmen is gezond.

- But this is not well-formed in 1^{st} order predicate logic: *Gezond(Zwemmen) ???*

Most

- Not all quantifiable expressions are expressible in predicate logic

- E.g. *de meeste (most)*
- *De meeste* cannot be expressed with ∀, ∃, or even a combination of ∀, ∃.

De meeste not expressable

Pretend that we extend 1st order predicate logic with a new quantifier M:

- MxPx is true if most individuals in the domain E have characteristic P

How do we then analyze the following sentence? :

De meeste kinderen slapen.

1. Mx $[Kind(x) \wedge Slapen(x)]$
2. Mx $[Kind(x) \rightarrow Slapen(x)]$

Both translations give the wrong truth conditions

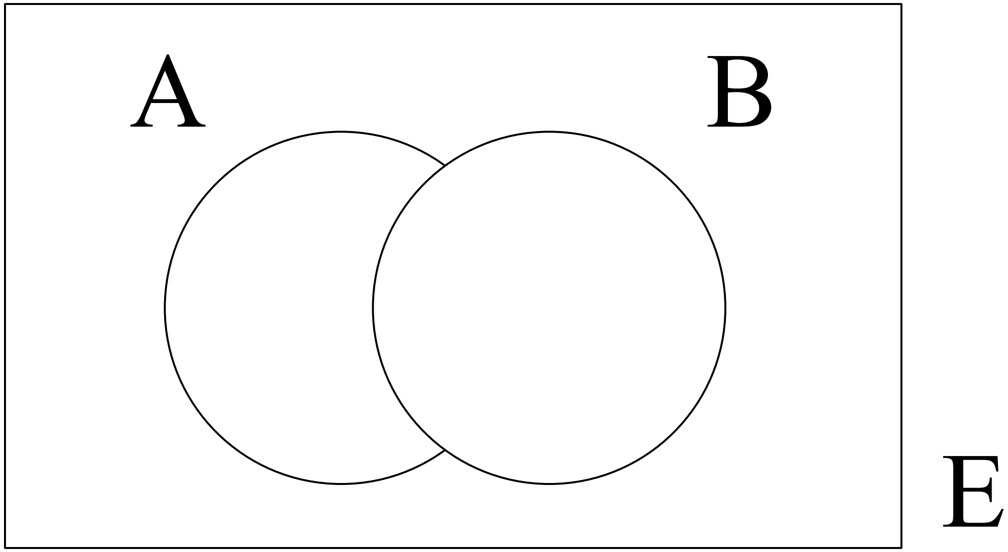
Where does *de meeste* go wrong?

- The meaning of *de meeste kinderen* can't be determined by looking at *de meeste individuen x*.
  - Quantification doesn't happen over all the individuals in the domain
  - Quantification only occurs over individuals that have the characteristic of being a child
- Conclusion: *de meeste* doesn't quantify over individuals, but quantifies over sets of individuals

Higher order predicate logic

- Quantification over sets ➔ higher order logic necessary:
- Generalized quantifier theory:
  - Determiners are understood as relations between sets of individuals
  - Truth conditions of sentences with determiners can be formulated as conditions on the relationships between a set A and a set B

Generalized Quantifiers



Det (A) (B) is true if …

Truth conditions

- ALLE (A)(B) is true if $A \subseteq B$.
- ENKELE (A)(B) is true if $A \cap B \neq \emptyset$.
- GEEN (A)(B) is true if $A \cap B = \emptyset$.
- MINSTENS VIJF (A)(B) is true if $|A \cap B| \geq 5$.
- DE MEESTE (A)(B) is true if $|A \cap B| > |A - B|$.

The interpretation of NPs

- The interpretation of NPs like *de meeste kinderen* is nou a set of sets
- To see this we have to look at proper names: these can be characterized as a set of characteristics
  - For example: Beatrix is koningin van Nederland, draagt vaak hoedjes, woont in paleis Noordeinde, is moeder van Willem Alexander, etc.
  - All these sets describe Beatrix as an individual
- Because characteristics are modelled as sets of individuals, we can also characterize proper names as sets of sets

The interpretation of NPs

- Beatrix has a certain characteristic X, that characteristic is a member of the set of characteristics that describe Beatrix
-
  - For proper names we can always switch from the level of individuals to the level of sets of sets
  - With quantified NPs we can't do that, they never refer to individuals
- An NP such as *alle studenten* always refers to characteristics that all students have: registered at a university, follow lectures, etc.

Nobody

From *Through the Looking-Glass* from Lewis Carroll:

"Who did you pass on the road?" the King went on, holding out his hand to the Messenger for some more hay.

"Nobody," said the Messenger.

"Quite right," said the King: "this young lady saw him too. So of course Nobody walks slower than you."

"I do my best," the Messenger said in a sullen tone. "I'm sure nobody walks much faster than I do!"

"He can't do that," said the King, "or else he'd have been here first. [...]."

Next time…

- Pragmatics