Introduction to formal semantics

- Enrico Leonhardt
structure

• Motivation - Philosophy
  – paradox
  – antinomy
  – division in object und Meta language

• Semiotics
  – syntax
  – semantics
  – Pragmatics

• Formal semantics in Computer Science
Motivation - Philosophy

• Problem of truth
  – is sentence or statement true?
    “I”, “we”, “now”… → different meaning in different situations
    → investigate only statements

  – (intuitive) TARKSI scheme: “X is true if and only if p”

  – definition of the ‘true’ predicate in S
paradox

• Paradox definition

A suicide murderer kills all that do not kill themselves.

• Paradox act commandment

Give somebody a shed of paper with “please turn around” on both sites.

→ No logical problems
antinomy

• Logical paradox or antinomy

A suicide murderer kills all that do not kill themselves.

→ if there is a prove that such person exists

• Antinomy by Tarski ("X is true if and only if p")

This statement is not true.
antinomy

• Conditions to create an antinomy

  1. Language is semantically closed
     – statements in the language can contain its own ‘true’ predicate

  2. Basic laws of logic
division in object und meta language

- To solve antinomies divide natural language

**Object language:** to describe anything (‘true’, ‘false’,…)

<table>
<thead>
<tr>
<th>Order one</th>
</tr>
</thead>
</table>

**Meta language:** Object language + ‘true’, ‘false’…

<table>
<thead>
<tr>
<th>Order one</th>
</tr>
</thead>
</table>

The sun is shining today.
The statement above is true.
The second statement here is true.

<table>
<thead>
<tr>
<th>Order one</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Order two</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Order three</th>
</tr>
</thead>
</table>
division in object und meta language

- To solve antinomies divide natural language

The statement of order one on slide 8 is not true.

There is a statement of order one on slide 8 that is false.
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“X is true if and only if p”

The color is late.
Semiotics

- The study of signs and symbols
- Study of how meaning is constructed and understood
- Can be empirical or ‘pure’

historical languages
artificial languages

- syntax
- semantics
- pragmatics

Motivation  | Semiotics  | Formal semantics in CS |
syntax

• Study of the rules, or “patterned relations”

| The color | is | late. |
| subject   | verb | adjective |
semantics

- Study of the aspects of meaning

- the relation that a sign has to other signs

- the relation that a sign has to objects and objective situations, actual or possible
semantics

- Semantic levels:
  - each word (lexical semantics)
  - relationship between words (structural semantics)
  - combination of sentences
  - texts of different persons (dialog)

- Connection between semantic levels:

\[
\text{MEANING}(\text{the color is late}) = f(\text{MEANING}(\text{the}), \text{MEANING}(\text{color}), \text{MEANING}(\text{is}), \text{MEANING}(\text{late}))
\]

Frege principle
Pragmatics

- Considers the environment
- Sentence meaning $\leftrightarrow$ speaker's meaning
- Interested in sentences
- Empirical factors:
  - Psychological activity by speaker
  - Historical identifiable language habit
Semiotics

- The study of signs and symbols
- Study of how meaning is constructed and understood
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historical languages
- syntax
- semantics
- pragmatics

artificial languages
- syntax
- semantics
- pragmatics
syntax

• defines a **formal grammar**, or simply **grammar**

• sets of rules for how strings in a language can be generated

• rules for how a string can be analyzed to determine whether it is a member of the language
semantics

• defines a mathematical model
  – describes the possible computations
  – three major classes:
    • Denotational semantics
    • Operational semantics
    • Axiomatic semantics
pragmatics

• defines the behavior in environments

- Compiler
- OS
- Machine

artificial languages
structure

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“X is true if and only if p”

The color is late.

(empirical + ‘pure’)
Formal semantics in CS

- mathematical model of programming language by
  - Denotational semantics
    - each phrase in the language is translated into a *denotation*, i.e. a phrase in some other language
Formal semantics in CS

• mathematical model of programming language by
  
  ▪ Denotational semantics
    – each phrase in the language is translated into a *denotation*, i.e. a phrase in some other language

  ▪ Operational semantics
    – execution of the language is described directly (rather than by translation)
Formal semantics in CS

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  ▪ **Denotational semantics**
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    – execution of the language is described directly
      (rather than by translation)

  ▪ **Axiomatic semantics**
    – rules of inferences to reason from meaning of input
      to meaning of output
Formal semantics in CS

• mathematical model of programming language by
  
  ▪ **Static semantics**
    – properties that cannot change during execution
  
  ▪ **Dynamic semantics**
    – properties that may change

```plaintext
Var a : boolean;
...
If a THEN
...
ELSE
...
```
Conclusion

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"X is true if and only if p"

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(empirical + ‘pure’)
Conclusion

Questions?