IA165
Combinatory Logic for Computational Semantics

Spring 2012

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PART I

- General Information about the course on "CL for CS"

- 12 lectures + 1 revision session from 24.02.2012 to 18.05.2012
- Class composition: lecture (1h) + classwork (45h)
- Friday from 12h to 1:50p.m
- Evaluation:

  Homework (30%) + Final exam. (50%) + Attendance (10%) + Participation (10%)
- Contact teacher: qkang@fi.muni.cz office: B206
- Course web page:

  https://is.muni.cz/auth/course/fi/spring2012/IA165

Objectives

- Introduce the Combinatory Logic and its application to Computational Semantics

  : How the CL can be applied to semantic analysis of natural language

- Be familiar with a practical technique of constructing semantic representations of natural language and discover the properties of natural language

Main readings

- H. Curry and R. Fey, Combinatory Logic, Vol1&2, 1958.
- P. Blackburn and Johan Bos, Representation and Inference for Natural Languages: A First Course in Computational Semantics, CSLI Publications, 2005.
- J.R. Hindley and J.P. Seldin, λ-calculus and Combinators: An introduction. Cambridge Univ. Press.

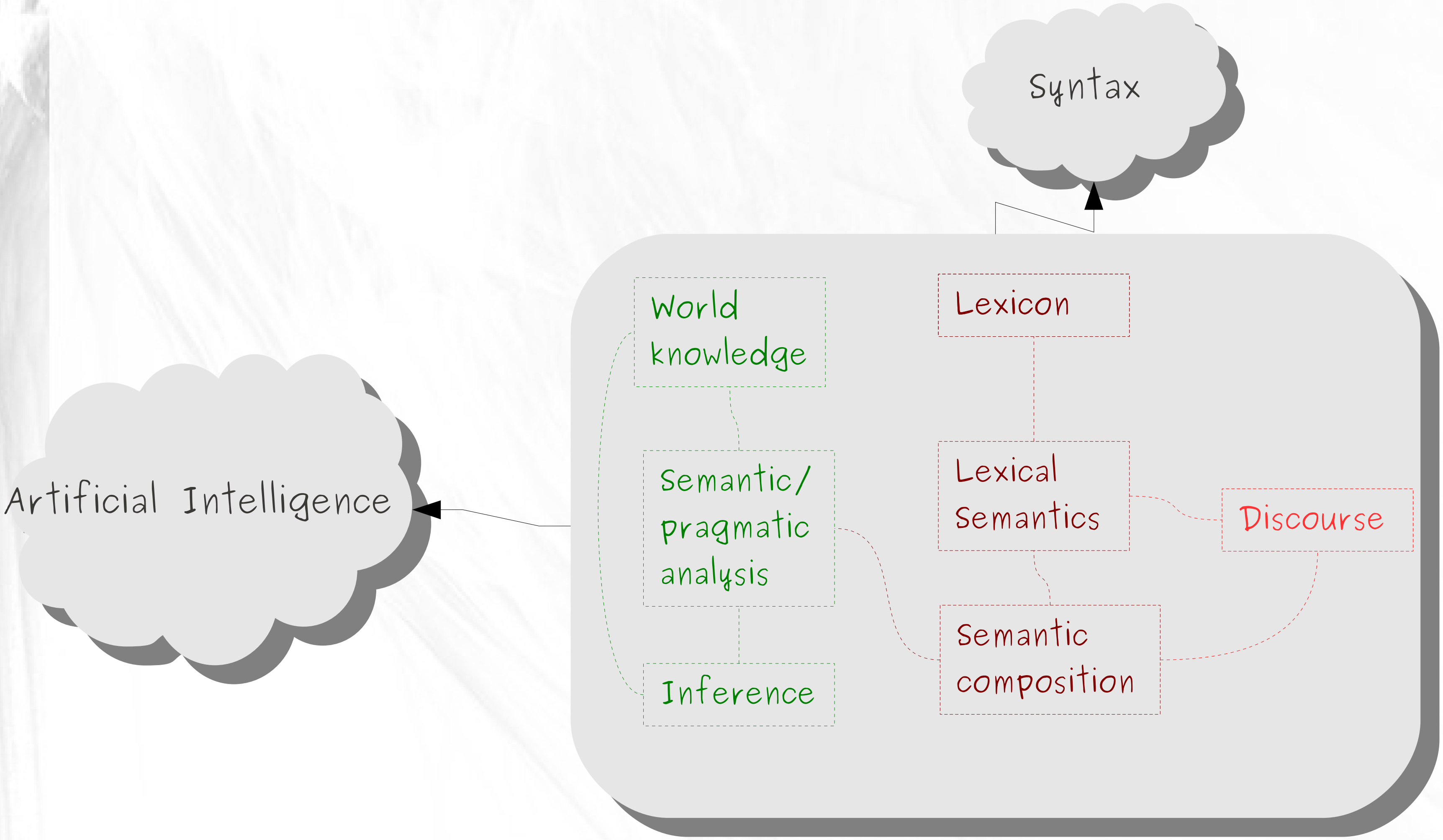
PART II

Background on Computational Semantics

Why the Computational Semantics?

- Promising approach for many domain-embedded applications is to use the benefits of statistical models for disambiguation at a lexical/syntactic level, and then to use logical semantic representations for detailed interpretations

Overview on Formal semantics



Landscape from M. Kohlhase's working paper (2010)

Traditional Topics of CS

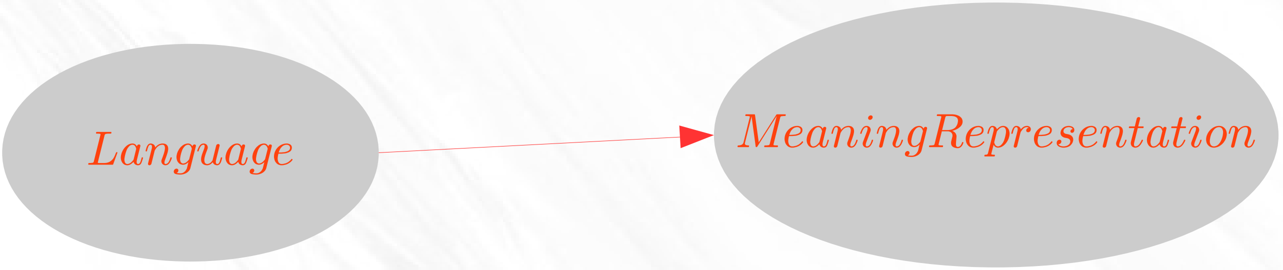
- Construction of meaning representation
- Semantic underspecification
- Anaphora resolution
- Presupposition projection
- quantifier scope resolution—formal semantics
- Statistical semantics

→ point of contact with lexical semantics

word sense disambiguation, semantic role labeling

What to do

- How can we automate the process of associating semantic representations with expressions of natural language?



Logical tools used in builiding meaning representation

- Use of First-Order Logic
- Use of Lamda-Calculus
- Use of Combinatory Logic
- Use of Type Theory
- Use of Propositional Logic
- Use f Modal Logic
- Various dynamic approaches (DRT, DPL...)

→ translating such simple sentences as "John loves Mary" and "A woman walks" into formal semantic representations → being systematic

Building a Semantic representation

- We need to complete he next three steps:

  step 1: specify the reasonable syntax for the natural language fragment of interest

  step 2 Specify semantic representations for the lexical items.

  step 3 Specify the translation of constituents compositionally.

$\forall x(MAN(X) \rightarrow WALK(x)$ in first-order formula

$(\lambda x.love(x, mary))(john) \Rightarrow love(john, mary)$ in lambda term

What we mean by "systematic"

- In First-Order Logic,

John loves Mary

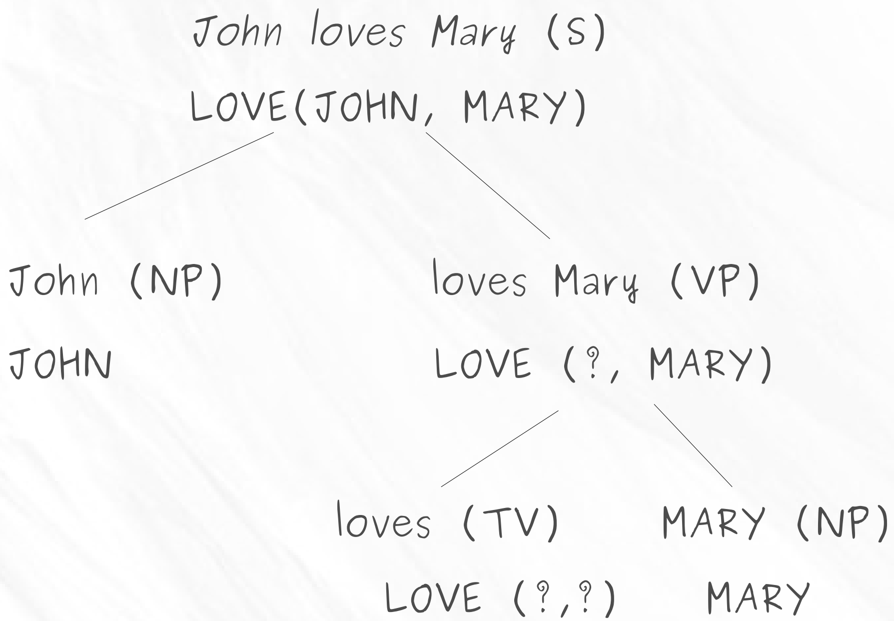
Semantic content is captured by the first-order formula :

LOVE(JOHN, MARY)

abstract denotation

How to be systematic

- Notion of syntactic structure



Summing up

- Building meaning representation

  1)lexical items

  2)syntactic structure

  3)from syntax to semantics

→ tell us how the semantic constructions of the parts of a sentence are to be joined together.

Syntax-semantic interface

- How to build a complete first-order formula?

  - The mecanism we're can mention is **λ-calculus.**

  That is, lambda calculus is viewed as a notational extension of first-order logic : new operator for binding variables → **λ**

ex: simple λ-expression

λx.woman(x)

Function -argument structure

« A function is a rule of correspondence by which when anything is given (as argument) another thing (the value of the function for that argument) may be obtained. That is, a function is an operation which may be applied on one thing (the argument) to yield another thing (the value of the function)... »

—A.Church (1941)

Concepts for Functional application

- operator
- Function
- Syncategoreme
- Incomplete expression

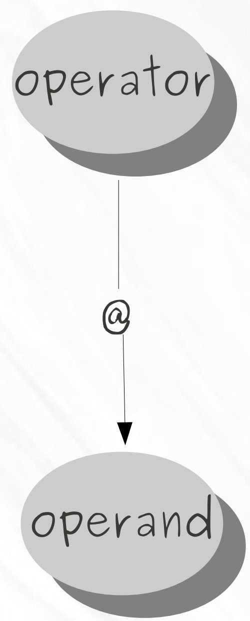
vs.

- operand
- Argument
- Categoreme
- Complete expression

#Non chronological order
· Incomplete expression theory of Frege (1879)
· "Logische Untersuchungen" (the distinction between dependent expression and independent expression) of Husserl (1900)

- All linguistic expression are viewed as **operators** or **operands.**

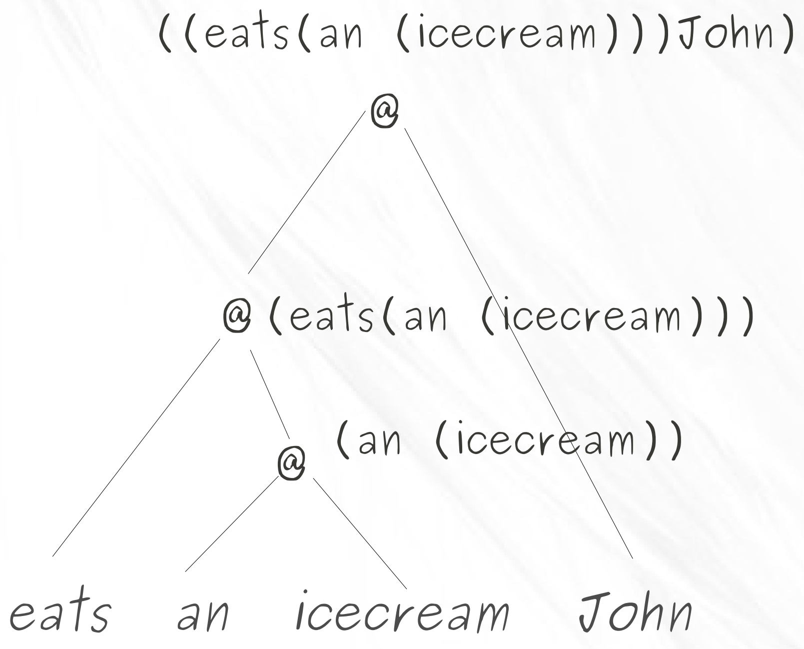
Conventional notation: (operator(operand))

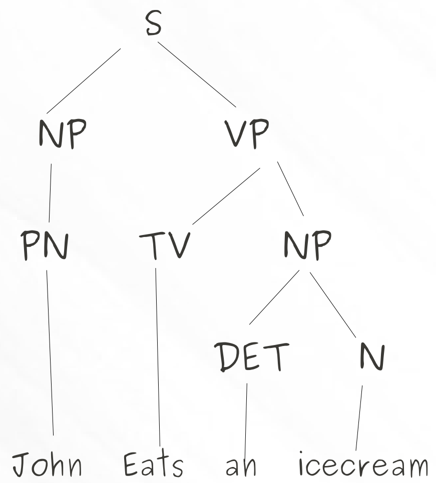


Verbes, adverbes,
prepositions, conjonctors,
negation, punctuation...

Noun phrase, Sentence

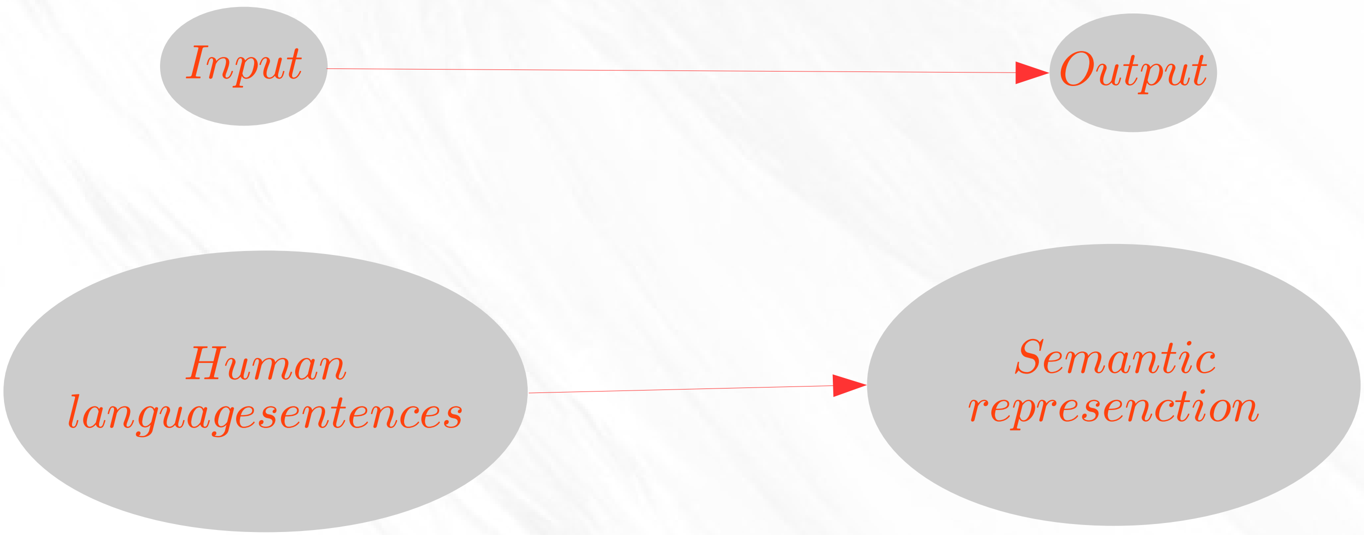
- One example: *John eats an icecream*





Computing semantic representation

- How do we automate the process of assigining semantic representations to sentences of human language?



- Two main approaches

1) use of the unification

2) use of the lambda calculus

→ They both requires a grammar describing the syntactic structure of the fragment of language of interest.

$$\begin{bmatrix} phon\text{: woman} \\ syn\text{: noun} \\ sem\text{:} \begin{bmatrix} index\text{: } \boxed{1} \\ content\text{: WOMAN(}\boxed{1}\text{)} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} phon\text{: a} \\ syn\text{: det} \\ sem\text{:} \begin{bmatrix} index\text{: } \boxed{3} \\ restr\text{: } \boxed{1} \\ scope\text{: } \boxed{2} \\ content\text{: } \exists\boxed{3}(\boxed{1}\wedge\boxed{2}) \end{bmatrix} \end{bmatrix}$$

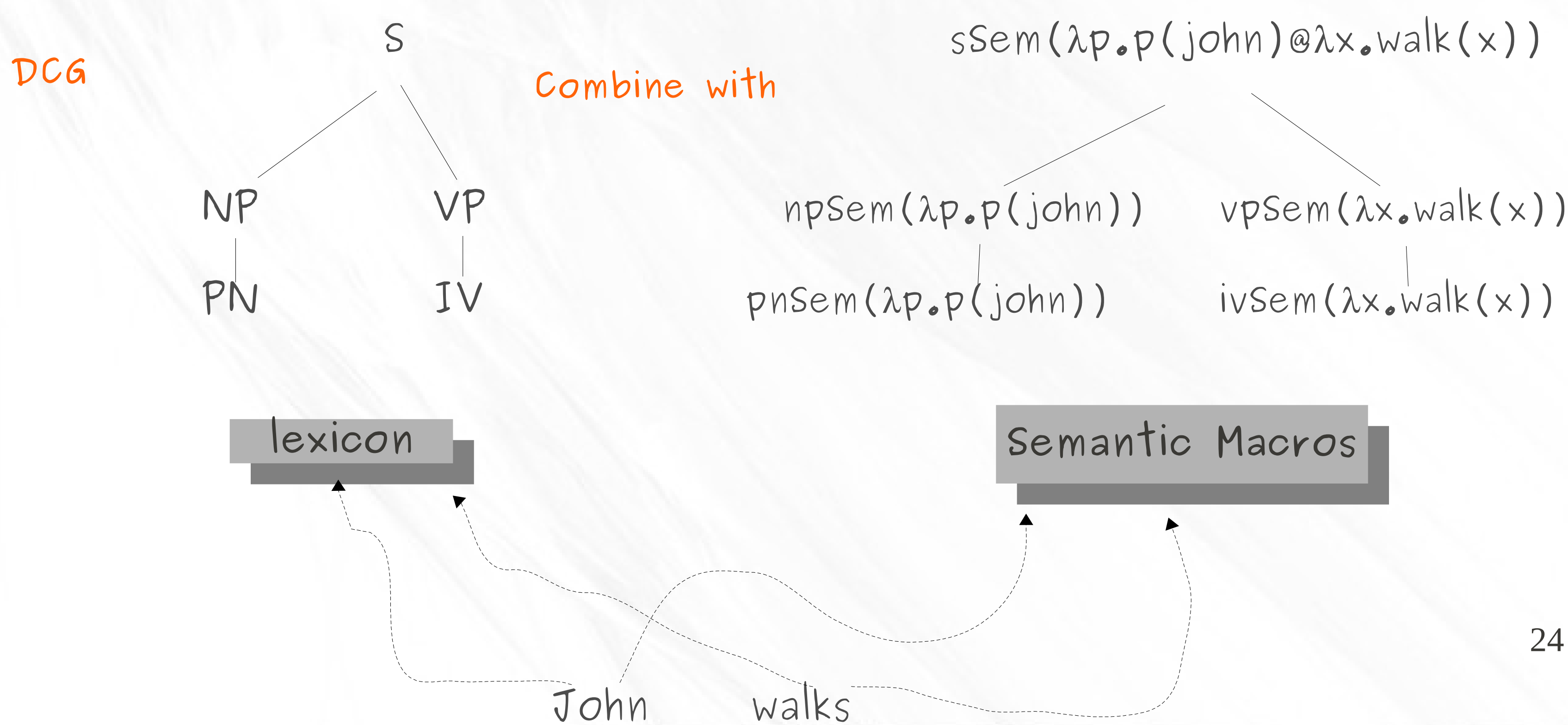
$$\begin{bmatrix} phon\text{: walks} \\ syn\text{: iv} \\ sem\text{:} \begin{bmatrix} index\text{: } \boxed{1} \\ content\text{: WALK(}\boxed{1}\text{)} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} phon\text{: a woman walks} \\ syn\text{: s} \\ sem\text{:} \begin{bmatrix} content\text{: } \exists\boxed{1}(\text{WOMAN(}\boxed{1}\text{)}\wedge\text{WALK(}\boxed{1}\text{)}) \end{bmatrix} \end{bmatrix}$$

$\exists$x(WOMAN(x)$\wedge$WALK(x))

Semantic construction system

- One example of a <u>modular implementation of a semantic construction system</u> by Burchardt, Koller and Walter



- Various ways to construct logical formulae as meaning representations for sentences

→ How to do useful work with such meaning representation?

↓

> Finding out what can be inferred
> from the formula constructed for a sentence
> is a very important task in Computation Semantics.

Next week...

- We will view the **Combinatory Logic** as a logical tool for representing a semantic meaning.