Natural Language Semantics

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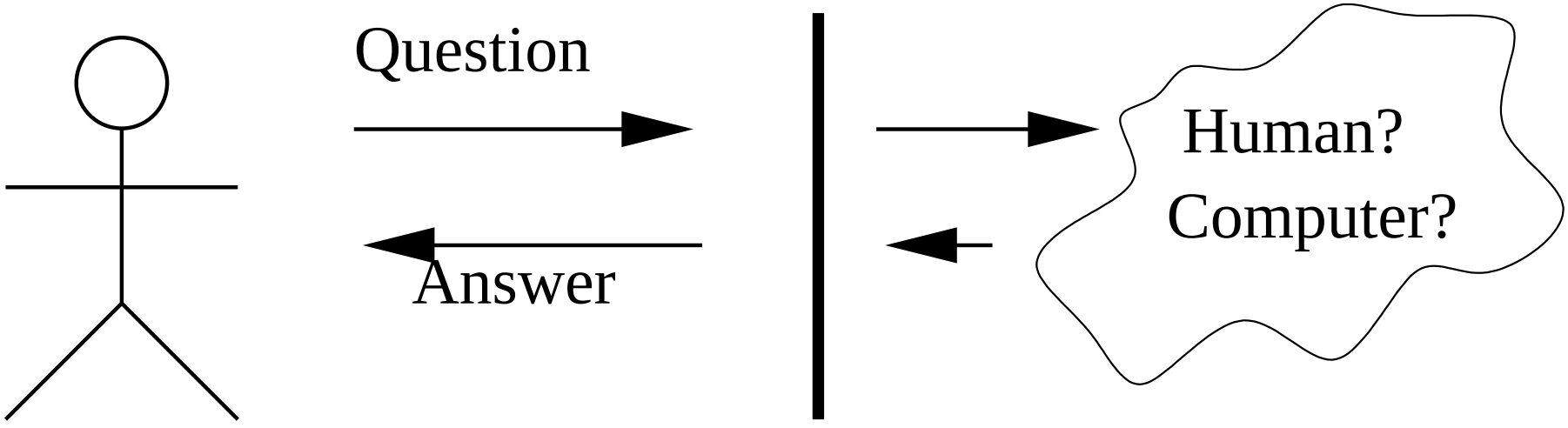
Outline

1. Motivation ($\rightarrow$ Turing Test)
2. How is NL–Semantics defined?
3. Is NL–Semantics compositional?
4. How do different sentences interact? ($\rightarrow$ Discourse Representation Theory)
5. Non–compositional approaches
   - Verb frames
   - Parsing & annotation

Turing Test



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Semantics Definition

Verb = Main Predicate

- Alice loves Bob = $love(Alice,\ Bob)$
- Alice loves a man = $\exists x.(man(x) \wedge love(Alice,\ x))$
- Every woman loves Bob =
  $\forall x.(woman(x) \rightarrow love(x,\ Bob))$
- Every woman loves a boxer =
  $\exists x.(boxer(x) \wedge (\forall y.(woman(y) \rightarrow love(y,\ x))))$
- Every woman loves a boxer =
  $\forall y.(woman(y) \rightarrow \exists x.(boxer(x) \wedge love(y,\ x)))$

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Compositionality Problem

Words are in the “wrong” order

- Alice loves Bob = $love(Alice,\ Bob) \rightsquigarrow$
  love, Alice, Bob
- Alice loves a man = $\exists x.(man(x) \wedge love(Alice,\ x)) \rightsquigarrow$
  a, man, love, Alice, . . .
- . . .

Sidestep: λ–Calculus

- Function abstraction:
  $\lambda x.(function\ expression)$
- Function application:
  $expression_1\ expression_2$
- β–Reduction:
  $(\lambda x.(function\ expression))\ argument =$
  $function\ expression[x/argument]$

Semantics with λ–Terms

Special λ–term for every word class

Proper names:	Alice	= $\lambda P.(P@Alice)$
Common names:	woman	= $\lambda y.(woman(y))$
Intransitive verbs:	walks	= $\lambda x.(walk(x))$
Transitive verbs:	loves	= $\lambda X.(\lambda z.(X@(\lambda x.love(z,\ x))))$
“every”:	every	= $\lambda P.(\lambda Q.(\forall x.((P@x) \rightarrow (Q@x))))$
“a”:	a	= $\lambda P.(\lambda Q.(\exists y.((P@y) \wedge (Q@y))))$

Does it really work?

Alice loves Bob =

$$(\lambda P.(P@Alice))@((\lambda X.(\lambda z.(X@(\lambda x.love(z,\ x)))))@(\lambda P.P@Bob)) =$$
$$(\lambda P.(P@Alice))@(\lambda z.((\lambda P.P@Bob)@(\lambda x.love(z,\ x)))) =$$
$$(\lambda P.(P@Alice))@(\lambda z.(\lambda x.love(z,\ x)@Bob)) =$$
$$(\lambda P.(P@Alice))@(\lambda z.love(z,\ Bob)) =$$
$$(\lambda z.love(z,\ Bob))@Alice =$$
$$love(Alice,\ Bob)$$

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Sentence Interaction

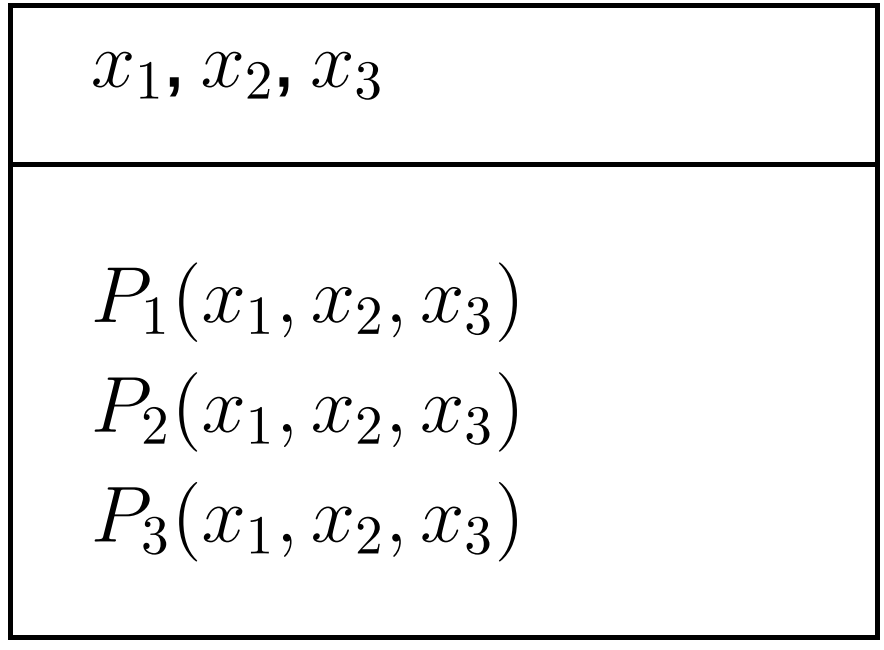
Alice is a woman. She loves Bob.

What is a possible λ–term for “she”?

Sentence Interaction

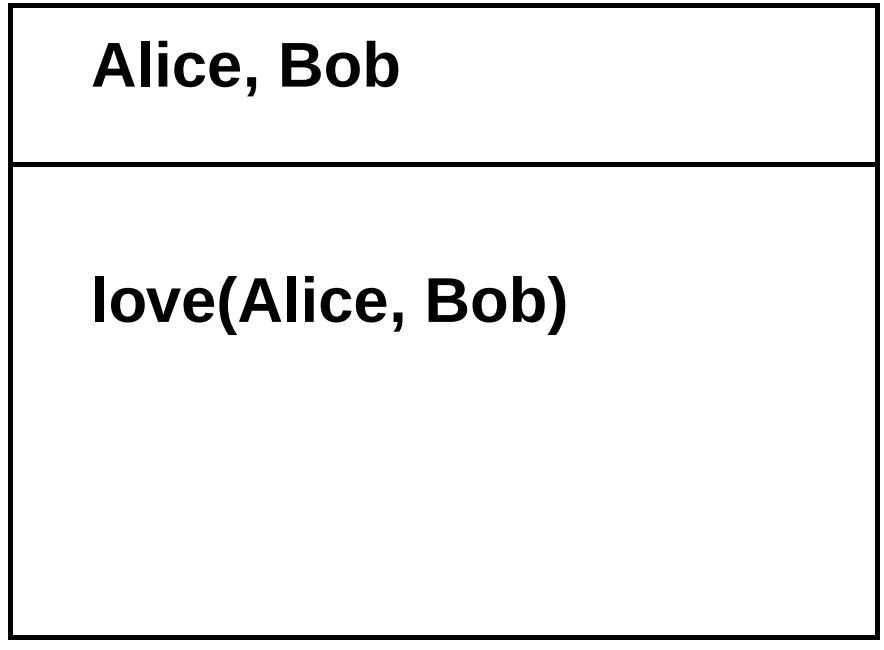
There is no λ–term for “she”!!!

Discourse Representation Structures 1/4



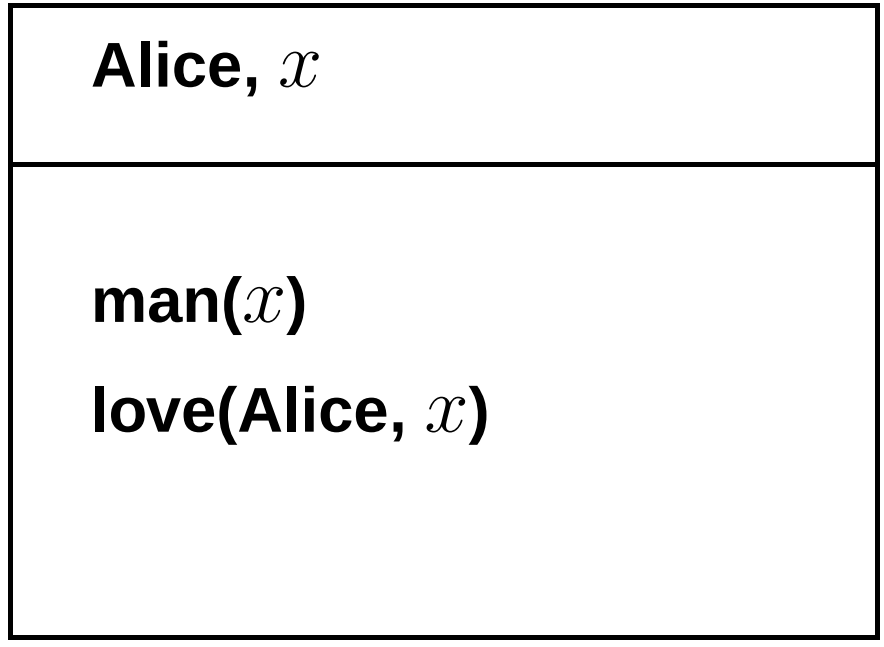
Discourse Representation Structures 2/4

Alice loves Bob



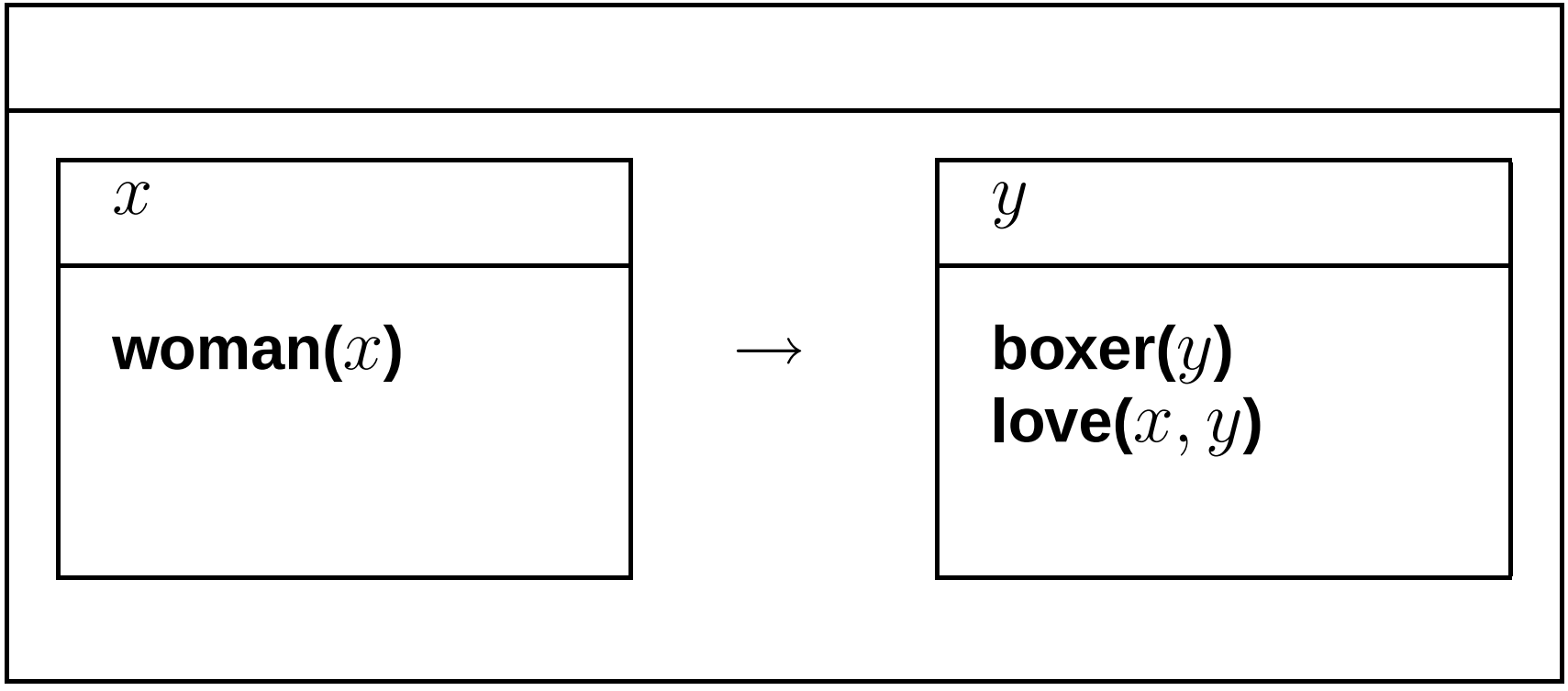
Discourse Representation Structures 3/4

Alice loves a man



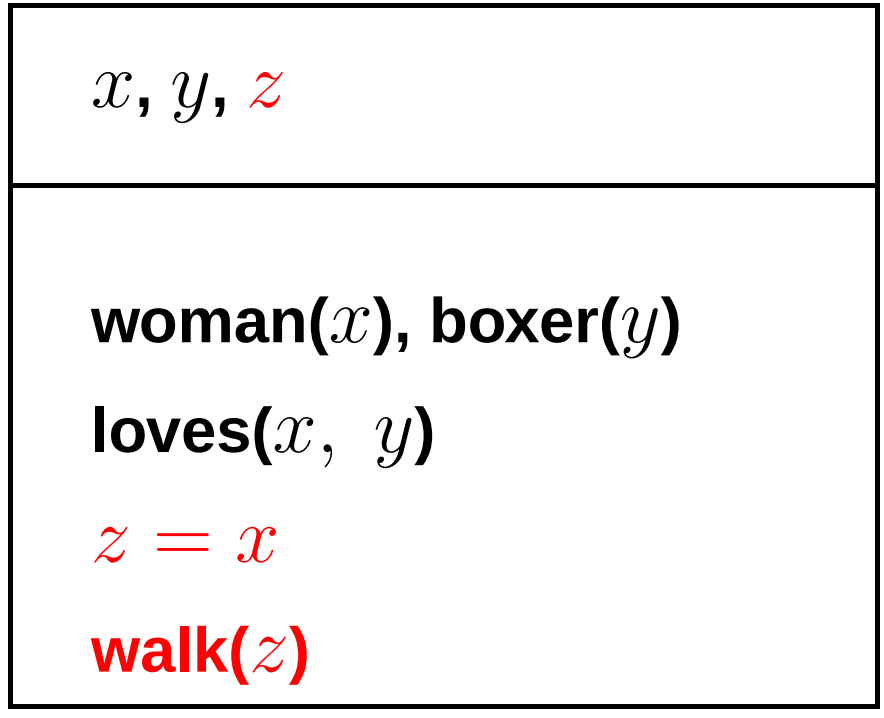
Discourse Representation Structures 4/4

Every women loves a boxer



Anaphora Resolution

A woman loves a boxer. She walks



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Verb Frames

Verb frame = verb with its arguments

Component X *sends* message Y to component Z=

send (Component X, message Y, component Z)

Verb frame defines:

- Verb type (predicate type)
- Predicate argument structure

Sidestep: Part–of–Speech Tagging

Each word is assigned a Part–of–Speech tag:

Coponent X sends message Y to component Z $\rightsquigarrow$

Component/NN X/NN sends/VBZ message/NN Y/NN to/TO component/NN Z/NN

Verb Frames as Templates

```
template
name=communication
  frame
    sender(POS=NN, syn=subject, sem=agent)
    comm-action(pos=VB, syn=verb-phrase,
                                  default='send')
    message (...)
    prep (..., default='to')
    receiver (...)
  end
```

Semantics Computation with Frames

- Finite number of possible frames
- POS–tagging as preprocessing
- Semantics computation is matching of actual sentences with predefined frames
  ($\rightsquigarrow$ POS–Sequence matching)

Frame example

Component/NN X/NN sends/VBZ message/NN Y/NN to/TO component/NN Z/NN $\rightsquigarrow$

Component/NN X/NN	sender
sends/VBZ	$send$
message/NN Y/NN	message
to/TO	
component/NN Z/NN	receiver

$\rightsquigarrow$ send (Coponent X, message Y, component Z)

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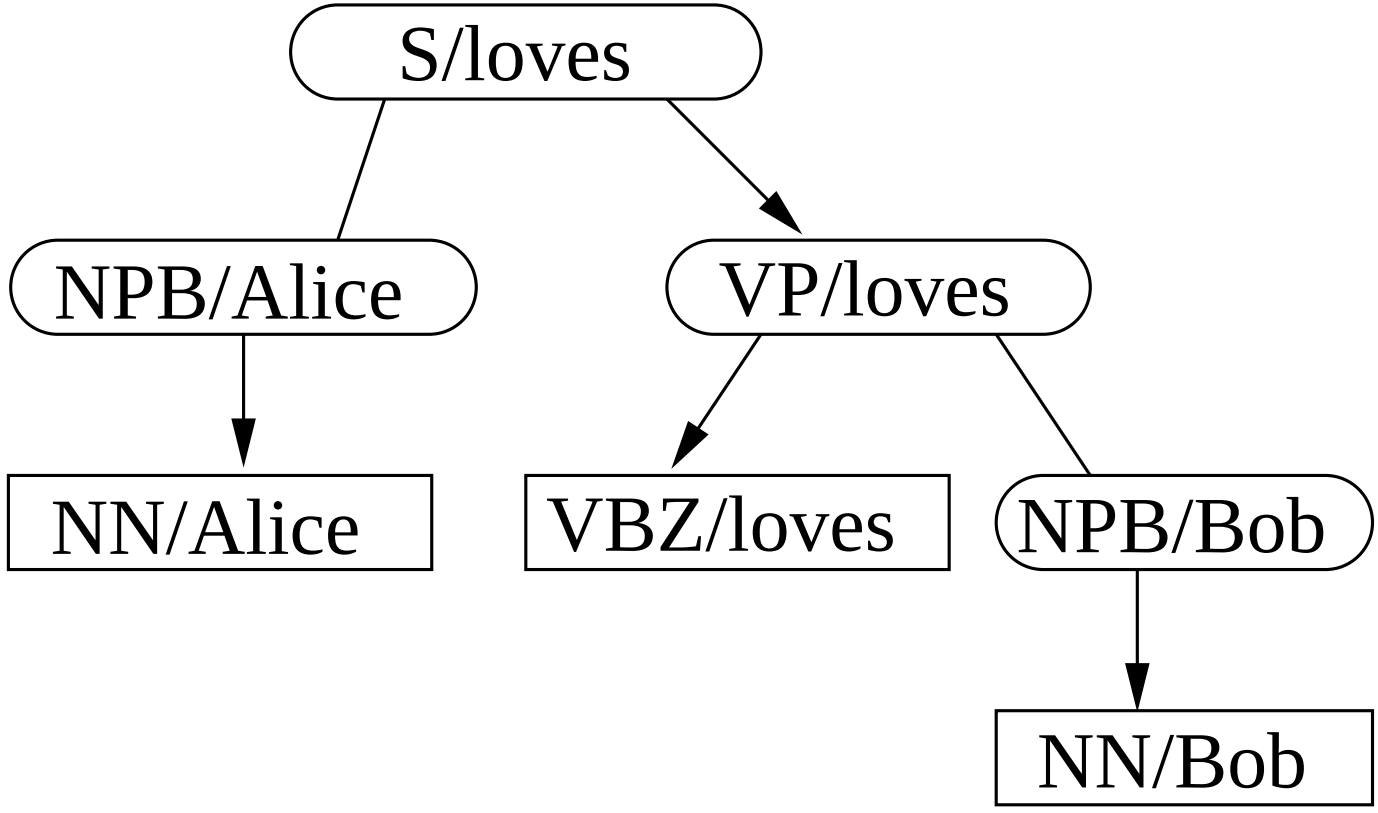
Sidestep: NL Parsing

Oversimplified:

- Chomsky–2 Grammar
- Each rule is assigned a probability
- The parser calculates the most probable parse tree
- Probability distribution is calculated on the basis of manually crafted training data

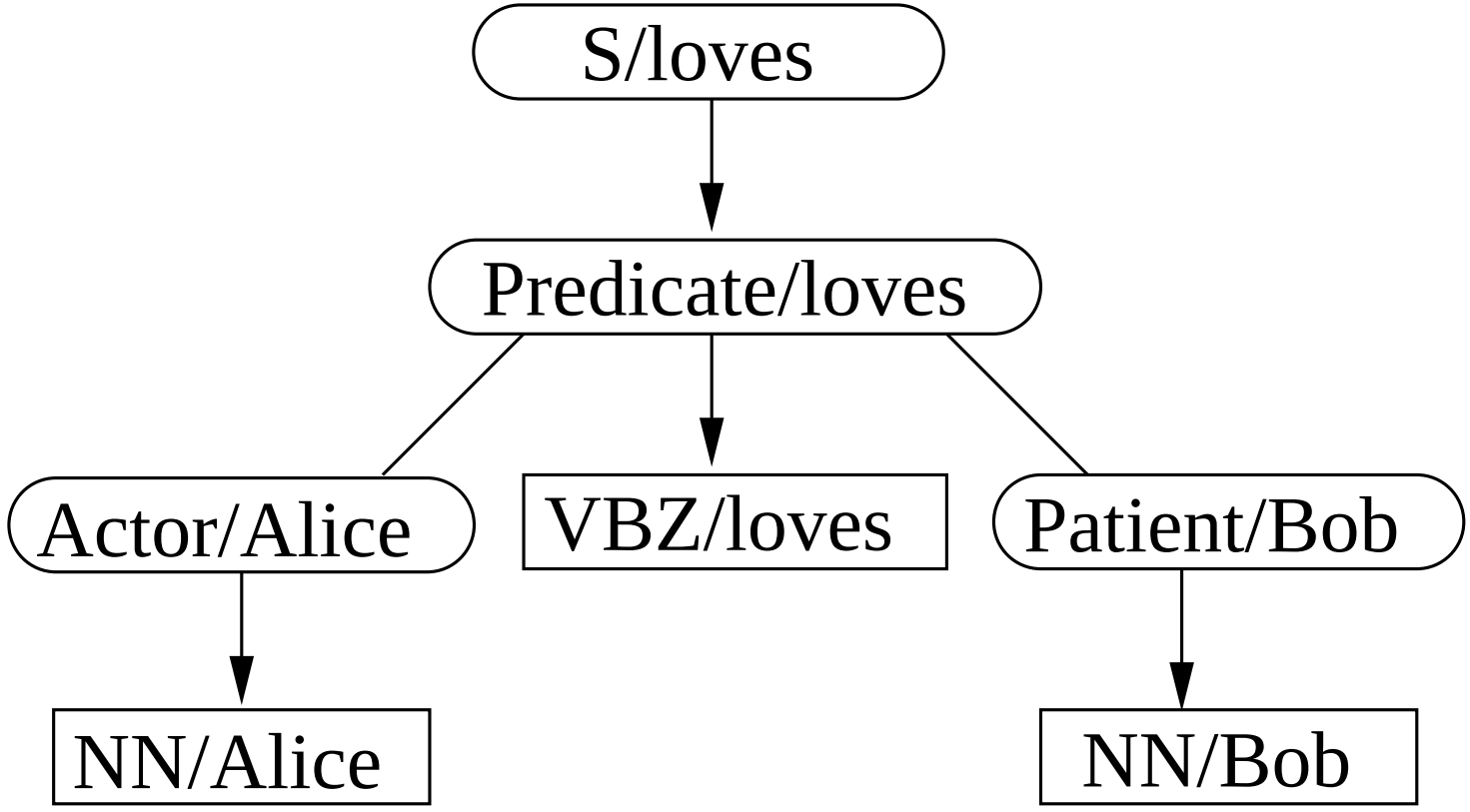
Training Data Example

Alice loves Bob =



Semantics Annotation in Training Data

Alice loves Bob =



Summary

- Goal: Extract predicates (verbs) with their arguments
- Firm and statistical approaches
- None is really working

That’s all, folks !!!