What can natural logic contribute to textual inferencing?

Natural Language Understanding
Textual Inferencing

From a theoretical point of view: how do we interpret texts?

Narrow this down to: which inferences can we draw from a short stretch of text?

- Entailments ~ Inferences
- Inferences based on language ~ world knowledge
- Partial knowledge

The natural logic way of looking at the problem

- Two dimensions
- Proof theoretic derivations
- Close to linguistic surface form, reasoning on linguistic form

Why is it interesting?

Machine Computations

Psychological reality: very piecemeal understanding

- Lance Rips: proofs
- Philip Johnson-Laird: models

  Only syllogisms with simple quantifiers have been studied

  Tversky and Kaneman: probabilistic reasoning

  Tenenbaum and Goodman: Bayesian reasoning

Data that can be handled

Monotonicity

- A small bird was singing in the garden
    - → a small bird was singing
    - → a bird was singing in the garden

- No bird was singing
    - → No bird was singing in the garden
    - → No small bird was singing in the garden

Some Temporal relations: Allen Calculus

- The deal lasted through August, until just before the government took over Freddie.
    - → The deal lasted through August.
    - → The deal lasted until just before the gov't took over Freddie.
    - → The government took over after August

Data that might be more difficult

Implicatives: we can get the entailments but not the presuppositions

- Shackleton failed to reach the South Pole. → Shackleton didn't reach the South Pole.
- John forgot to turn off the stove. → John didn't turn off the stove.
- John forgot that he turned off the stove. → John turned off the stove

Factive presuppositions

- It is odd that the President doesn't know the difference between Sunnis and Shiites
- It is Bush who didn't know the difference between Sunnis and Shiites

Converses

- John is taller than Bill --> Bill is shorter than John
- Mary sold a book to Jane --> Jane bought a book from Mary

Data that are certainly going to be difficult

Spatial relations

- X is to the right of Y --> Y is to the left of X
- X is 20 miles from here, Y is 30 miles from here --> Y is farther from here than X

Presuppositions/conventional implicatures

Almost, nearly: negative but upward monotone!

Invited inferences

General Approach

Narrow swath rather than broad overview to show interaction among logical formalization, natural language facts and computational requirements.

What we covered

Examples of Natural Logic:

- Syllogism - logical system
- Monotonicity calculus: Sànchez, Dowty, Moss

Natural Logic and Computational systems:

- NatLog system
- Bridge

Sources of inferences

Entailment

Presupposition

Invited Inference

Attribution to a trusted source

Sources of inferences

Entailment

Presupposition

Is it odd that my mood is affected by WiFi strength?

=> My mood is affected by WiFi strength.

Invited Inference

Attribution to a trusted source

Sources of inferences

Entailment

It is the case that the Republicans have settled on a tactic of obstruction.

=> The Republicans have settled on a tactic of obstruction.

Presupposition

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Invited Inference

CIA was able to lead Pakistan to the suspected Bali bomber.

=> CIA led Pakistan to the suspected Bali bomber.

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Invited Inference

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=> CIA led Pakistan to the suspected Bali bomber.

Attribution to a trusted source

FDA announced that there is a link between breast implants and a very rare form of blood cancer.

=> There is a link between breast implants and a very rare form of blood cancer.

Attributions to a Source

We tend to accept as veridical what is attributed to a trusted source by positively biased of neutral reports.

Four factors to consider:

the provenance of the text (NYT or National Inquirer)
the source
the reporter
the stance of the reporter

Positively biased reporting verbs:

acknowledge, admit, agree, confess, point out, reveal, ...

Neutral reporting verbs:

announce, assert, declare, explain, indicate, mention, say, state, write, ...

Negative biased reporting verbs:

allege, claim, ...

Natural language form

Bag of words

Strings

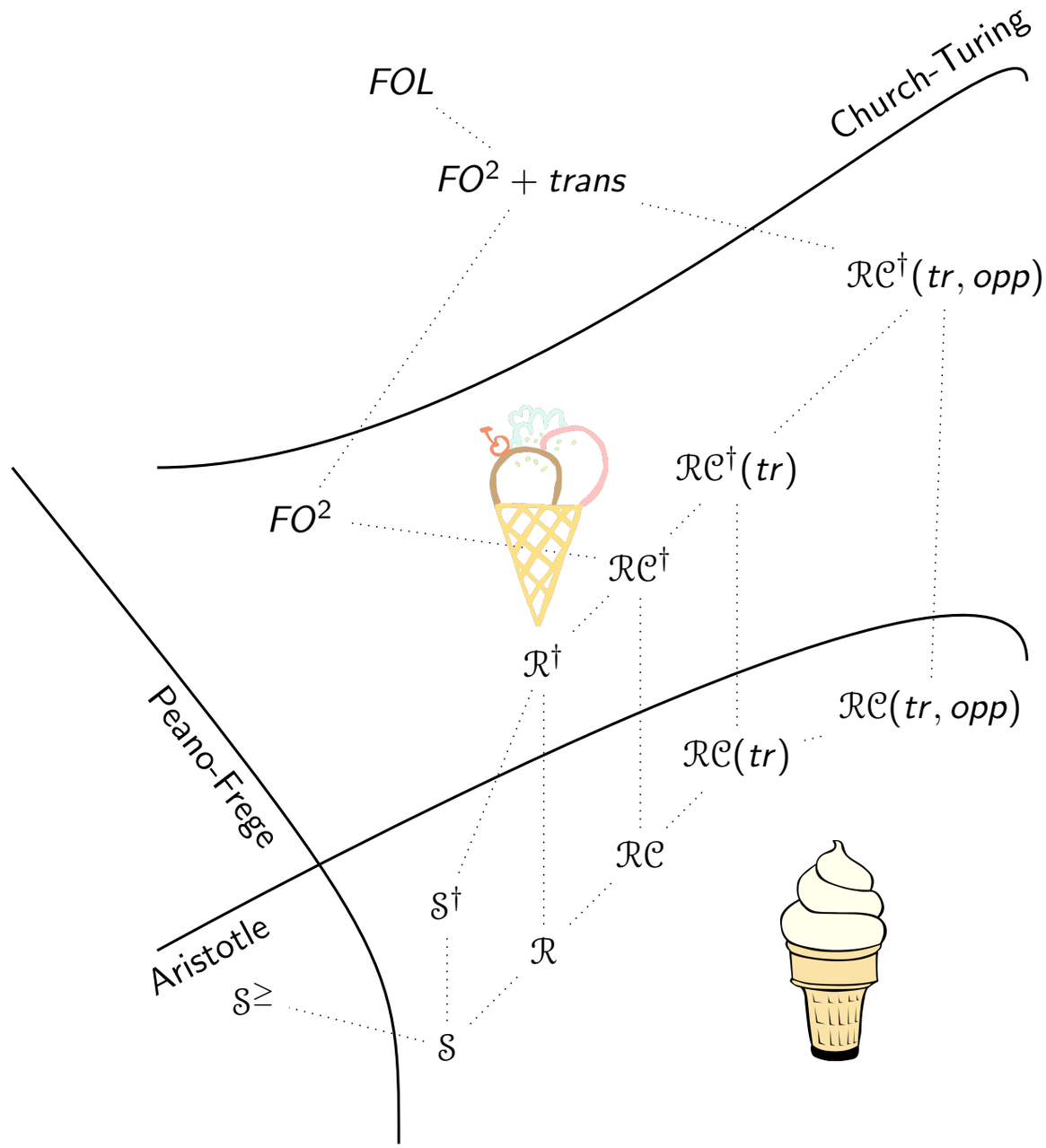
PS

Categorial grammar

Dependency grammar

Abstract representations

Logics of the first two flavors



first-order logic

FO^2 + "R is trans"

2 variable FO logic

† adds full N-negation

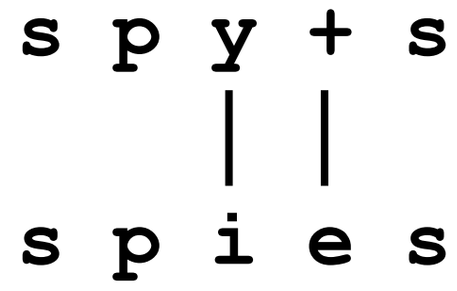
$\mathcal{RC}(tr)$ + opposites
$\mathcal{RC}$ + (transitive)
comparative adjs
$\mathcal{R}$ + relative clauses
$\mathcal{S}$ + full N-negation
$\mathcal{R}$ = relational syllogistic
$\mathcal{S}^\geq$ adds $|p| \geq |q|$
$\mathcal{S}$: all/some/no p are q

Complexity

Larry Moss and Ian Pratt-Hartmann have shown that while the systems below the “Church-Turing” boundary are decidable, sound and complete, the worst-case complexity of reasoning is exponential for even these simple systems. Does it matter? What would the ‘average complexity’ be?

We don’t know the answer but we know of a case where the theoretical worst-case complexity turned out to be irrelevant for practical applications.

In the mid 1980s there emerged a new paradigm for analyzing and generating inflected word forms. This was called two-level morphology. It was based simple constrains regulating symbol to symbol correspondence between lexical forms and surface forms.



In 1985 G. Edward Barton, published a proof showing that two-level morphology was NP-complete, even though it was implemented by simple finite-state transducers.

Barton showed that the SAT problem, the standard textbook example of an NP complete problem could be encoded by two-level constraints.

$$(\neg p \vee q) \wedge (q \vee r) \wedge (\neg p \vee r \vee \neg s) \ldots$$

Is there a consistent assignment of truth values to p, q, r, s, etc. that makes the formula true?

```
(p q) ∧ (q r) ∧ (p r s) ...
 | |     | |     | | |
(0 1) ∧ (1 1) ∧ (0 r 0) ...
```

SAT as a two-level problem:

- Satisfaction
  - There must be at least one 1 between every (...). -- Simple
- Consistency
  - If x is realized as 1 somewhere, it must be 1 everywhere. -- This is the exponential part.

Barton's complexity result turned out to be irrelevant for any practical applications

At this point most of natural logic doesn't go far beyond the traditional playing grounds of logicians: quantifiers.

MacCarthny shows it can go further but illustrates also some of the problems this raises.

Model-theoretic grounding: logical types, ontology ~ lexical items

Lexical items do not carry their semantic types on their sleeve.

Looking towards the future

Less concern for complexity results

More lexical semantic studies (conceptual and statistical); share diagnostic results with model-theoretical semantics

Better ontologies

Might need a more abstract representation than surface structure

Reflections

Textual inference is a good test bed for computational semantics.

- It is task-oriented. It abstracts away from particular meaning representations and inference procedures.
- It allows for systems that make purely linguistic inferences, others may bring in world knowledge and statistical reasoning.

This is a good time to be doing computational semantics.

- Purely statistical approaches have plateaued.
- There is computing power for parsing and semantic processing.
- Room to experiment with various approaches and combinations

There are enough of unsolved problems to keep you busy and maybe funded for many years to come.