Computing Weakest Readings: Failures and Perspectives

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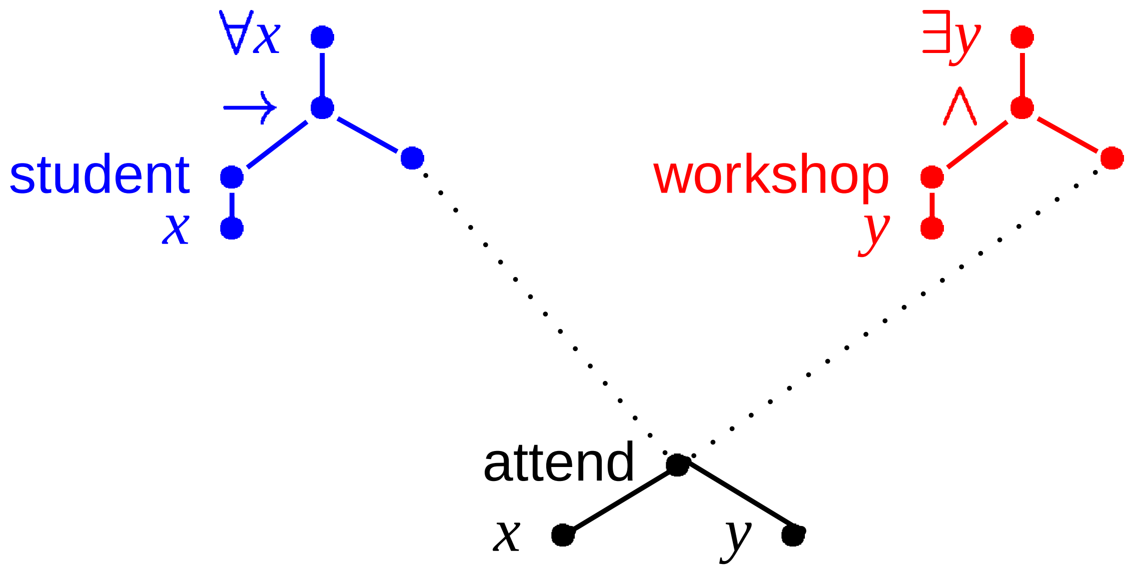
- Underspecification
- Eliminating Unsatisfiable Readings
- Weakest Readings
- Graph Rewriting: Problems and Perspectives

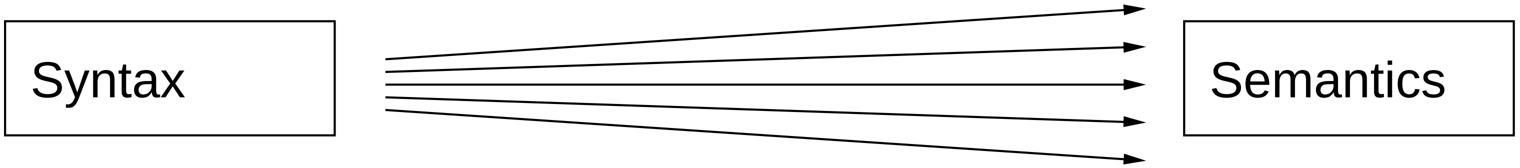
- Processing of ambiguities are one of the big challenges for computational linguistics.
- Problem: Number of readings grows exponentially with number of ambiguities.
- Underspecification: Represent all readings in a single, compact description.
- Try to work with descriptions as long as possible; delay enumeration of readings.
- Here: scope ambiguities (Alshawi & Crouch 92, Reyle 93, Muskens 95, Deemter & Peters 96, Pinkal 96, Egg et al. 98, . . .)

Every student attended a workshop.



(1) $\forall x.\text{student}(x) \rightarrow \exists y.\text{workshop}(y) \wedge \text{attend}(x, y)$
(2) $\exists y.\text{workshop}(y) \wedge \forall x.\text{student}(x) \rightarrow \text{attend}(x, y)$

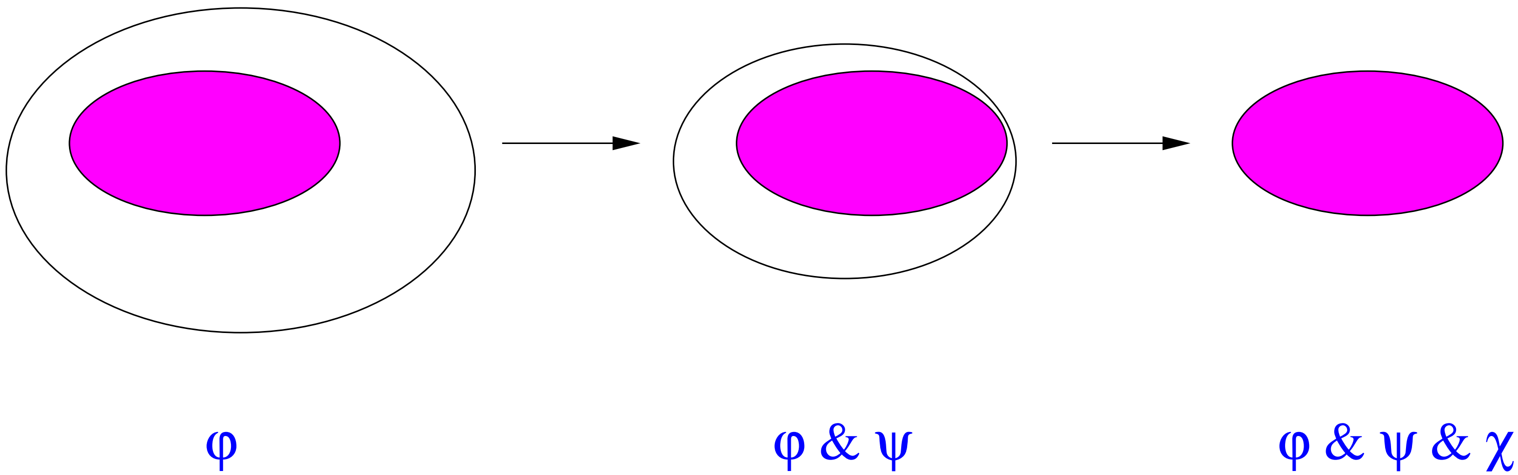
not underspecified: map syntax directly to many semantic readings



underspecified: new intermediate level of descriptions

Sometimes some readings are unsatisfiable:
Every boy ate a cookie.

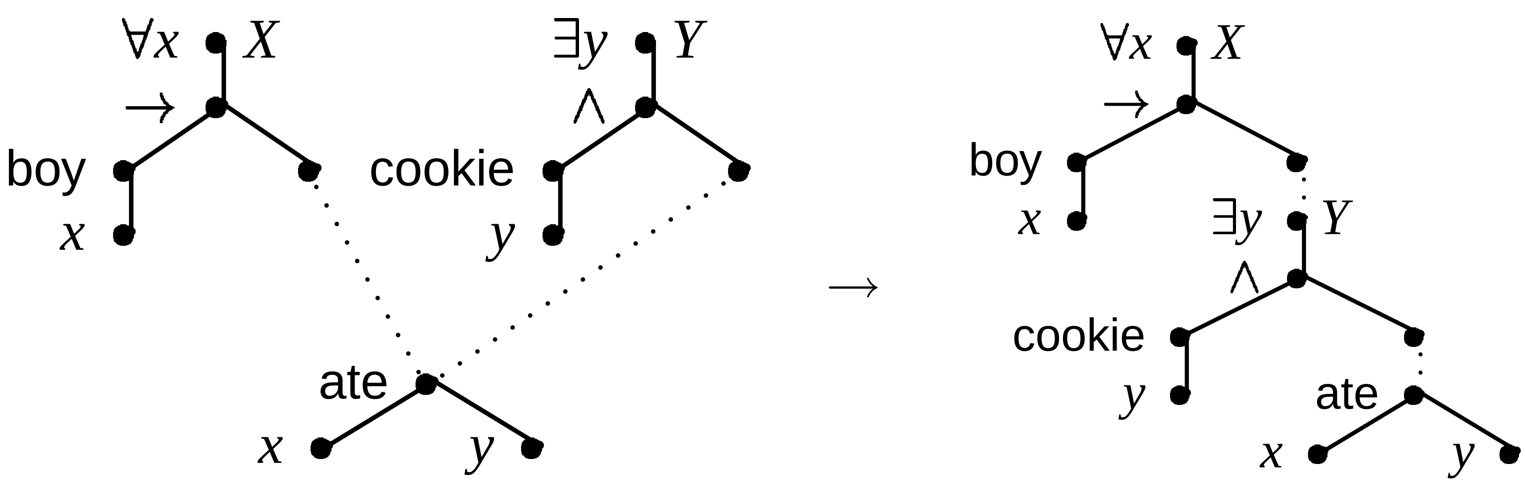
Goal: Strengthen the underspecified description to remove unsatisfiable (and other unwanted) readings.



Underspecification opens up the chance of eliminating unwanted readings without ever seeing them.

Eliminating Unsatisfiable Readings

Every boy ate a cookie.



Two readings are characterized by $X \lhd^* Y$ or $Y \lhd^* X$. Reading with $Y \lhd^* X$ is inconsistent with world knowledge, so can commit to $X \lhd^* Y$.

It can be done using the following algorithm:

1. Pick a node with two incoming dominance edges.
2. Consider the strengthened constraint $\varphi' = \varphi \wedge X \triangleleft^* Y$.
3. If all readings of φ' are unsatisfiable, go back to 1 with $\varphi \wedge Y \triangleleft^* X$.
4. Otherwise, do the same for $\varphi'' = \varphi \wedge Y \triangleleft^* X$. Then do the same for the other nodes with two incoming dominance edges.
5. Terminate if none of this was successful.

Main problem: How do we check whether all readings of φ' are unsatisfiable?

- First-order entailment $\mathbf{A} \models \mathbf{B}$ establishes a partial order on the set of readings.

- *Every man loves a woman*:
$$\exists\forall \models \forall\exists.$$

- Call the maximal elements of this order *weakest readings*.

- All readings of a constraint are unsatisfiable iff all weakest readings are unsatisfiable. This can be checked using a theorem prover.

- Weakest readings are independently interesting: Represent safe information.

- Are there always unique weakest readings?

Unfortunately, even very simple sentences do not have unique weakest readings.

Every student does not pay attention.

(1) $\forall x.\text{stud}(x) \rightarrow \neg \text{payatt}(x)$
(2) $\neg \forall x.\text{stud}(x) \rightarrow \text{payatt}(x)$

(1) $\not\models$ (2): models that contain no students

(2) $\not\models$ (1): some students pay attention, some don't

But intuitively, (1) is stronger than (2)!

- Strong NPs such as *every student* presuppose that their restriction is non-empty.

- Define a new entailment relation $\models_p$:

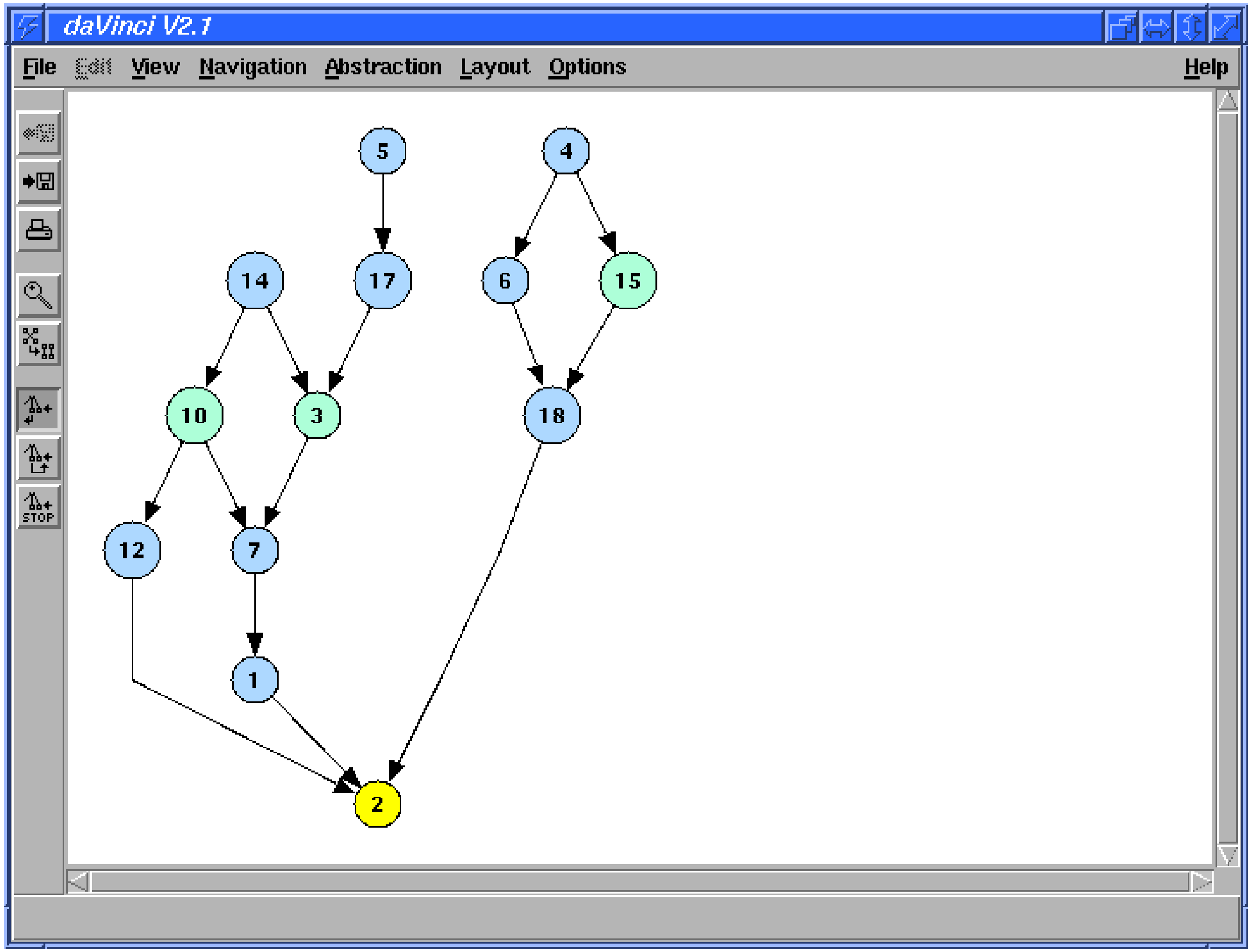
$$\mathbf{A} \models_p \mathbf{B} \quad :\Leftrightarrow \quad \mathbf{A} \cup \mathsf{pre}(\mathbf{A}) \models \mathbf{B},$$

  where $\mathsf{pre}(\mathbf{A})$ are the presuppositions of $\mathbf{A}$.

- Seems to solve the problem: (1) $\models_p$ (2).

- Weakest Readings Hypothesis: Every sentence has a unique weakest reading, given an appropriate notion of entailment.

Every researcher of a company does not see a sample.
(18 readings)



Weakest Readings Hypothesis May Be Wrong!

Unfortunately, there are sentences for which it is unclear whether they have a unique weakest reading.

A researcher of every company does not laugh.

Sentence has five readings. Two that are minimally strong are:

(1) $\forall y.(\mathsf{comp}(y) \rightarrow \exists x.(\mathsf{res}(x) \wedge \mathsf{of}(x,y) \wedge \neg \mathsf{laugh}(x)))$
"Every company employs a sad researcher."

(2) $\neg \exists x.(\mathsf{res}(x) \wedge \forall y.(\mathsf{comp}(y) \rightarrow \mathsf{of}(x,y)) \wedge \mathsf{laugh}(x))$
$\equiv \forall x.(\mathsf{res}(x) \wedge \forall y.(\mathsf{comp}(y) \rightarrow \mathsf{of}(x,y))) \rightarrow \neg \mathsf{laugh}(x)$
? "There is no researcher who works for every company and laughs."

$(2) \models (1)$ if there is a researcher who works for every company. But does the reading really presuppose that?

Weakest Readings Hypothesis May Be Wrong!

A researcher of every company does not laugh.

Even worse, if we assume that (2) is stronger than (1), we must also accept that (3) is stronger than (1) because $(3) \models_p (2)$.

(1) $\forall y.(\mathsf{comp}(y) \rightarrow \exists x.(\mathsf{res}(x) \wedge \mathsf{of}(x,y) \wedge \neg \mathsf{laugh}(x)))$
"Every company employs a sad researcher."

(3) $\neg \forall y.(\mathsf{comp}(y) \rightarrow \exists x.(\mathsf{res}(x) \wedge \mathsf{of}(x,y) \wedge \mathsf{laugh}(x)))$
"Not every company employs a happy researcher.", i.e.
"There is a company that employs only sad researchers."

But (1) and (3) are intuitively totally incomparable.

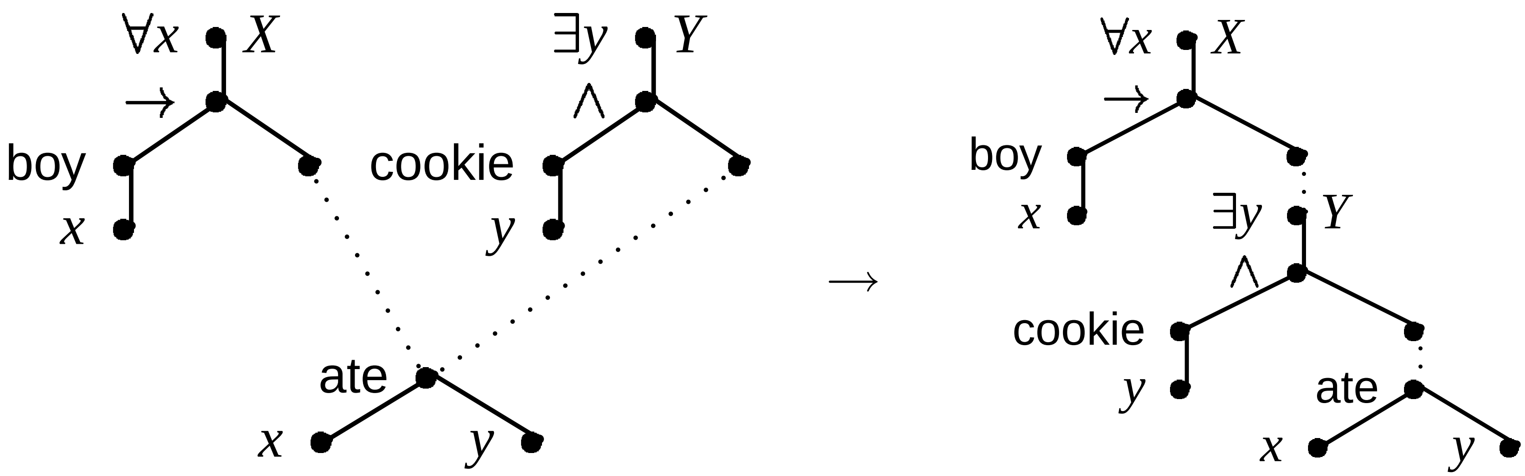
Now What?

- It seems we must abandon the Weakest Reading Hypothesis.
- Call minimally strong readings “weakest readings” from now on.
- Many sentences will still have a unique or only a few weakest readings – typically much fewer than total number of readings.
- For such sentences, we can still save a lot of work by working only with weakest readings.

- My initial approach to computing weakest readings: Successive manipulations of the constraint graph so described readings become increasingly weaker.
- Add one dominance edge in each step; this separates the set of readings into two halves.
- Rewriting system is sound iff whenever $G \rightarrow G'$, G and G' have the same weakest readings.
- Rewriting system is complete iff we always end up with a constraint graph that has only weakest (i.e. pairwise incomparable) readings.
- Compute the set of weakest readings by applying the rewriting rule to exhaustion, then solving the last constraint.

A Naive Graph Rewriting System

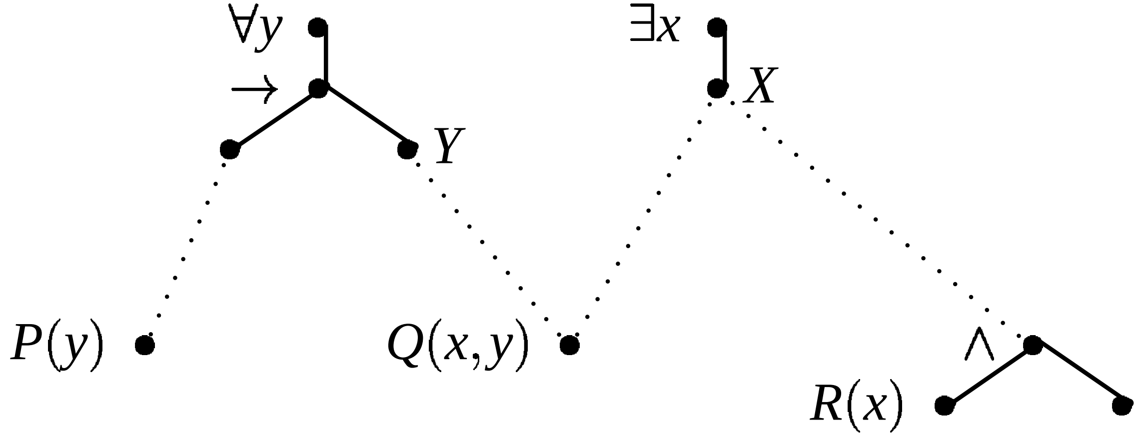
"Whenever there is a local scope ambiguity between an indefinite and the scope of a universal quantifier, give the universal wide scope."



Similar rules can be found for other combinations of ∃ and ∀.

Naive Graph Rewriting Doesn't Work

Unfortunately, this doesn't work even for rather simple (artificial) graphs:



Weakest reading if $X \lhd^* Y$: $\forall y.P(y) \rightarrow \exists x.(R(x) \wedge Q(x,y))$

Weakest reading if $Y \lhd^* X$: $\exists x \forall y.((P(y) \wedge R(x)) \rightarrow Q(x,y))$

The two readings are incomparable; so there is no sound and complete graph rewriting system that works for this constraint.

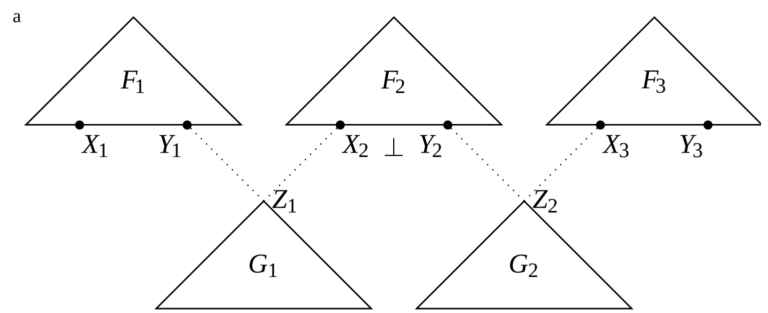
Fragments

- There is no graph rewriting algorithm that is sound and complete for all constraints in general.
- But maybe there is a restricted fragment of all constraints for which such an algorithm can be found!
- Have tried various fragments that are still too big for algorithms.
- Have found various fragments that are too small to be interesting.

A Candidate Fragment

- Constraints which are chains whose upper fragments are ordinary first-order quantifiers as they occur in natural language. (No artificial formulas.)

- No negations for now.



- Obvious soundness proof fails, but result may still be true.

- Need to generalize chains.

- Can define a nontrivial grammar that only generates chains.

The Next Steps

- Quest for a useful fragment that allows graph rewriting.

- Maybe graph rewriting is the wrong approach. Could also pick an arbitrary reading and weaken it successively.

- Weakening an arbitrary reading might lead to a formula that is not a reading, but still entailed by all real readings. But this might still be useful.

- Read up on indefinites and presuppositions.

Conclusion

- Want to compute weakest readings so I can remove whole classes of unsatisfiable readings in one step.

- There are sentences that don't have a unique weakest reading. Existential presuppositions of strong NPs help sometimes, but not always.

- Have explored graph rewriting to compute weakest readings.

- This doesn't work in general.

- Can I find a useful fragment of the general case for which it does?