Tree Transducers and Tree Adjoining Grammars

Historical and Current Perspectives

William C. Rounds
University of Michigan, Ann Arbor

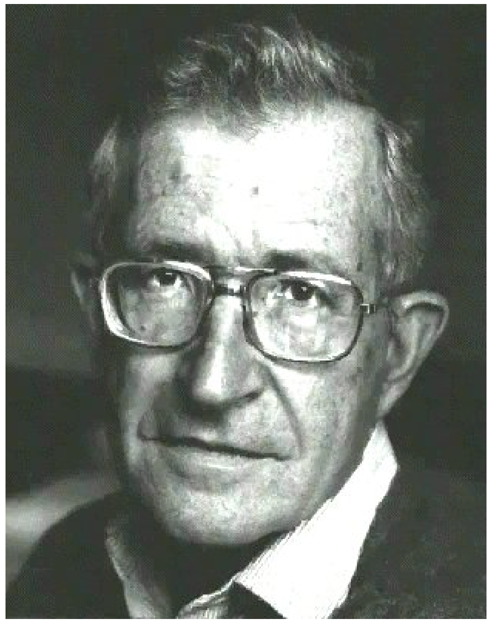
Outline

- Some history – genesis of tree transducers and tree grammars
- A little bit on the genesis of feature logic
- A preliminary attempt to unify transducers, TAGs, and feature logic
- A few questions about ongoing work

The 60's

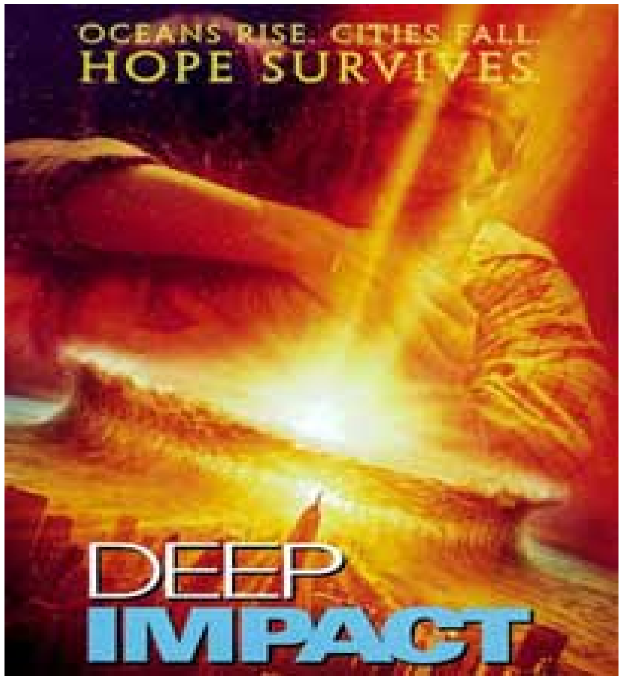
A new religion is born...

The Master



I become a disciple

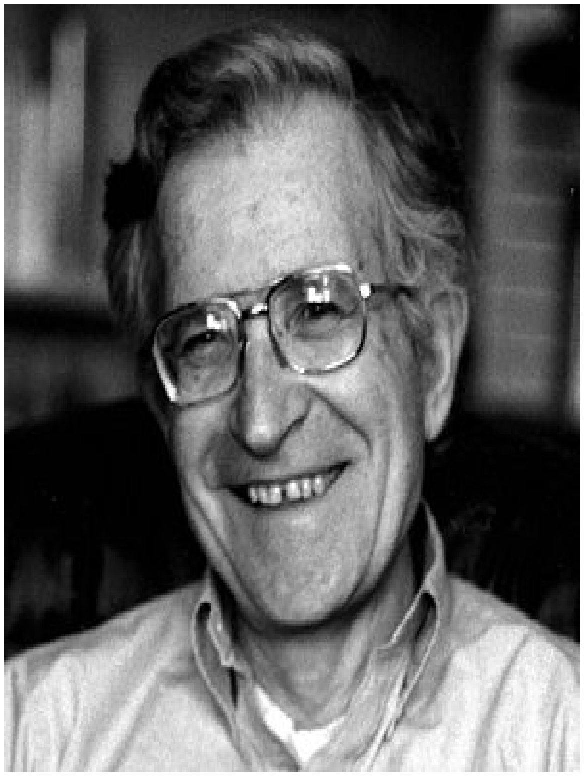
The Peters-Ritchie result



Transformational grammars are Turing-powerful

End times for TG?

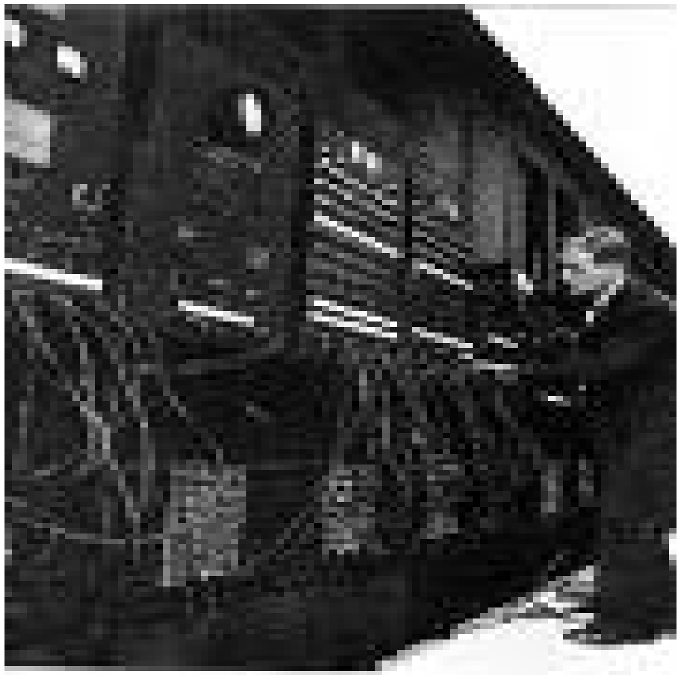
TG survives!



It begins series of mutations into GB, PP, MIN, REC

A failed Math PhD?

Go into computer science, but call it math



Problem

- Go beyond context-free (reduplication phenomena)
- Have recursion
- Avoid Turing-powerful
- Have a vague resemblance to transformational grammar

Tree automata – salvation!

Thatcher, Wright, Brainerd, Doner, Rabin

- Tree automaton - recognizable = context-free.
- Top-down infinite tree automata emptiness is decidable
- Idea - use top-down to define tree transductions
- Reinforced by being able to model syntax-directed translation (not for NL!)

Top-down tree transduction

Further developments

- Tree transducers which could delay (create their own input), now called macro tree transducers
- One-state macro tree transducer = CFG on trees
- Santa Cruz 1970 – Thatcher, Joshi, Peters, Petrick, Partee, Bach: Tree Mappings in Linguistics
- birth of TAGs, aka linear CFGs on trees
- Natural generalization to graph grammars, links to term rewriting
- Burgeoning industry in Europe, led by Engelfriet

What was I doing? (1976-1983)

- Some results on complexity
- Modelling semantics of concurrency
- Ignoring tree transducers
- Learning about bisimulations and modal logic

Learn from your graduate students

- Bob Kasper (1983-4): What is a disjunctive feature structure?
- How should these be unified?
- Write down desired laws for distributing unification over disjunction
- With the background of modal logics for concurrency, realize that feature structures are models for feature logic.
- PATR-2 actually invents feature logic; we extend to modal version.
- Make big mistakes proving a completeness theorem.
- Drew Moshier (1986-7), Larry Moss, Bob Carpenter fix things

Skip to the near present

- Probabilities, statistics, and corpora
- Resurgence of (weighted) finite-state transducers on strings as unifying model for speech recognition and generation algorithms (Mohri, Pereira, Riley)
- Kevin Knight and students propose probabilistic tree transducers as schemas for MT algorithms
- Multiplicity of tree transducer models (e.g., semilinear non-deleting deterministic, with inherited attributes and right-regular lookahead)
- Can we take any of these off the shelf and actually **use** them?

Two directions

- Use linguistic evidence to select relevant class of models (this workshop)
- Use various mathematical means to understand commonalities and differences among models
- Shieber: synchronous TAGS and tree transducers
- Rogers: TAGS as 3D tree automata
- Take a break from inventing the next variation

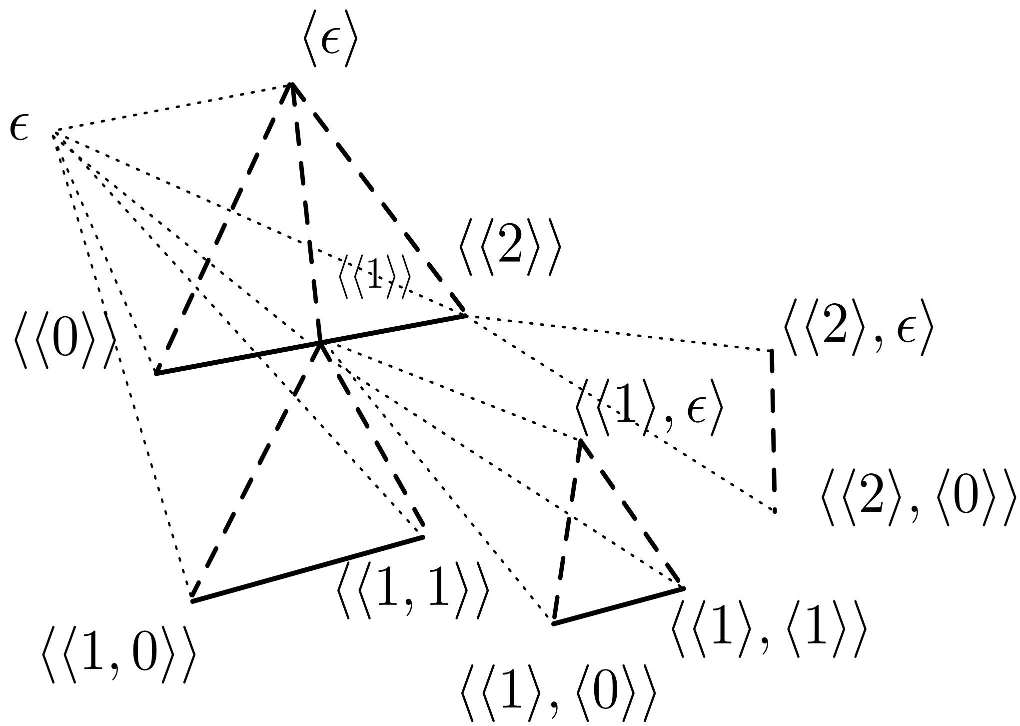
Model-theoretic syntax

- Long tradition of regarding generation as proof, even parsing as proof
- In last ten years: what is the model theory for these proof systems?
- Best-known example: Montague grammar (focus on interpretation)
- Now: type-logical syntax (Morrill, Moortgat) and type-logical semantics (Carpenter)
- Feature logic is another description language for syntax.
- Attempts to view grammatical derivations as proofs, usually in logic programs with feature logic as a constraint language.
- HPSG: fully developed linguistic theory grounded in feature descriptions and unification; grammars as logical constraints on feature structures.

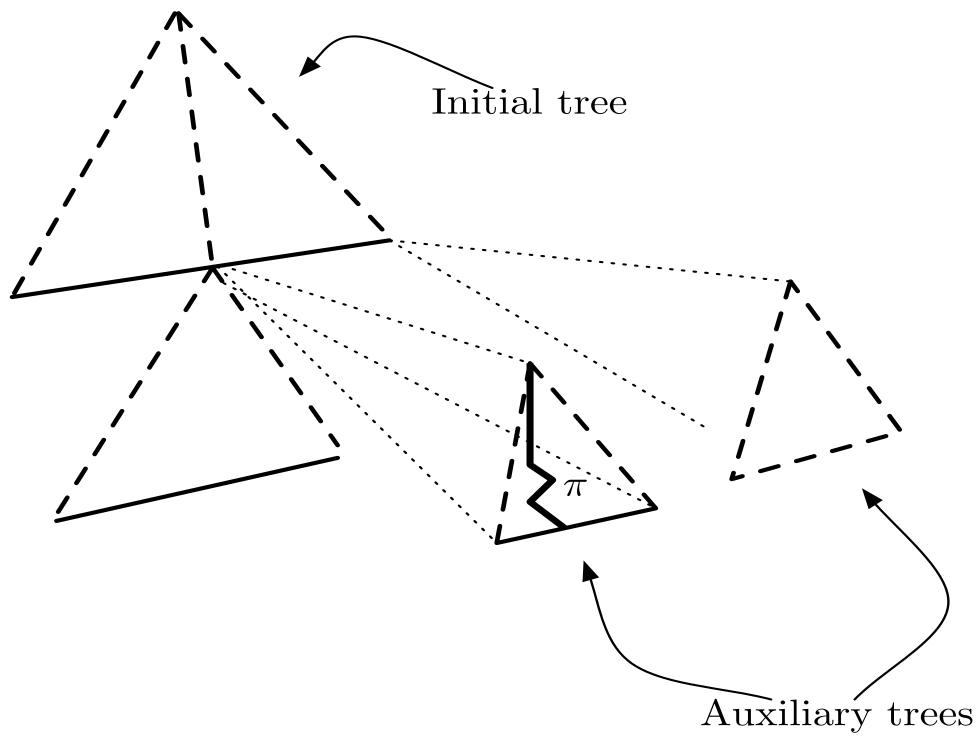
Clean proof theory and accompanying model theory for feature logic ?

- Incomplete and ongoing work
- Goals: self-contained proof theory (do not glue onto grammar)
- Logic should model common grammatical formalisms, to understand them better
- Some previous work: Keller (extending feature logic to model TAGs); Vijay-Shanker and Joshi (FTAGs)

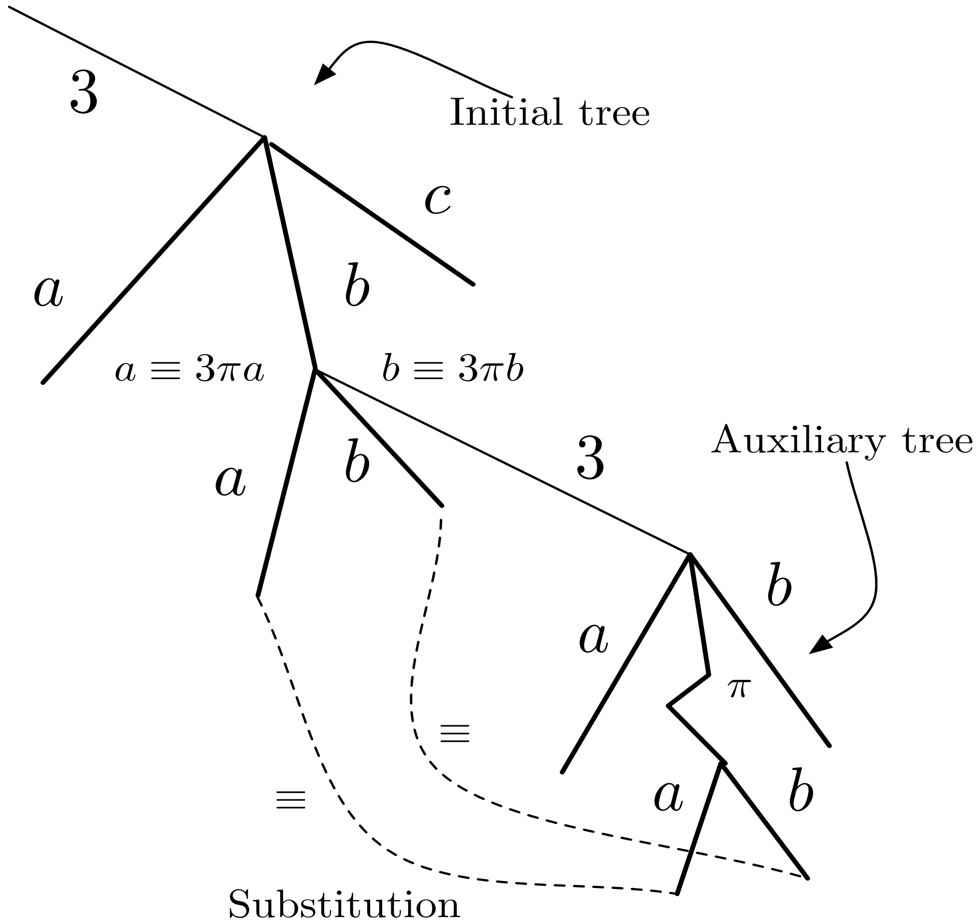
Three-dimensional trees (Rogers)



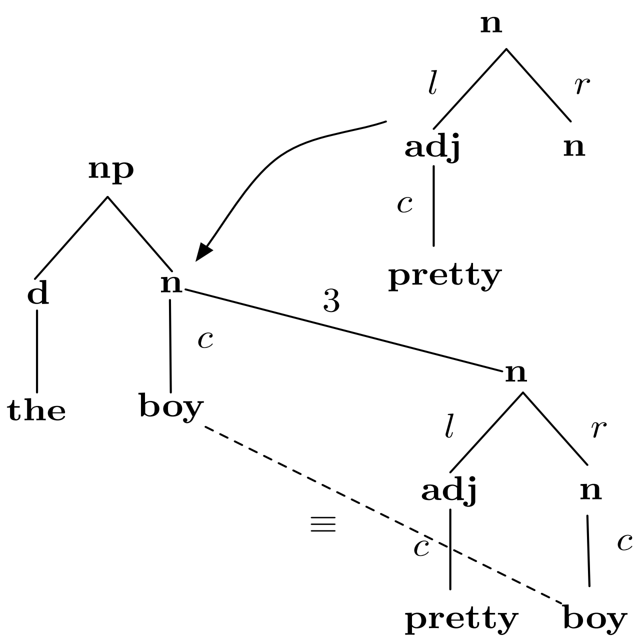
Adjunction as a 3D tree



Adjunction as a 3D FS



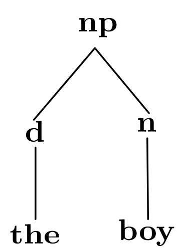
Example of Adjunction Rule



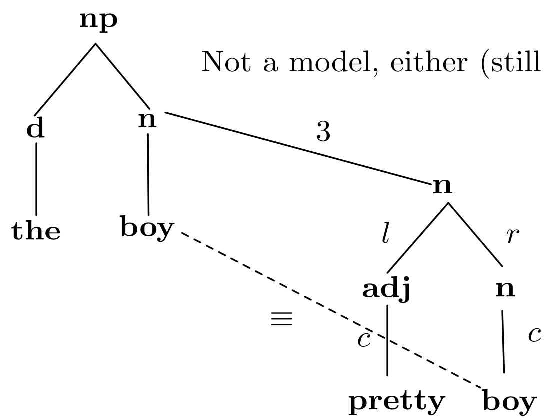
$$n[c{:}\bot] \rightarrow \{3{:}n[l{:}\underline{adj}[c{:}\text{pretty}], r{:}n[c{:}\bot]] \sqcup (c \doteq 3rc),$$
$$3{:}\underline{n}[c{:}\bot] \sqcup (c \doteq 3c)\}$$

Choice

Rules as logical constraints



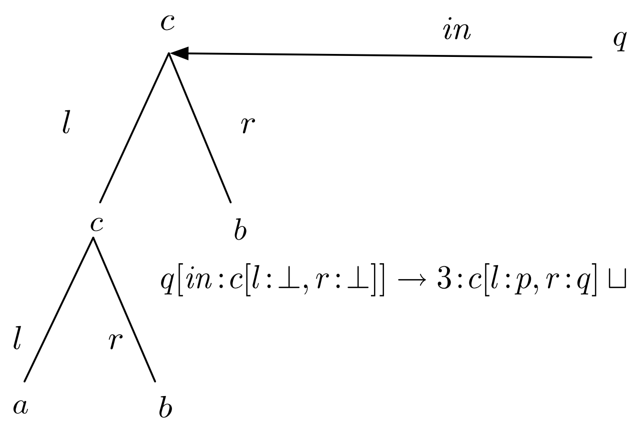
Not a model



Not a model, either (still unexpanded ns)

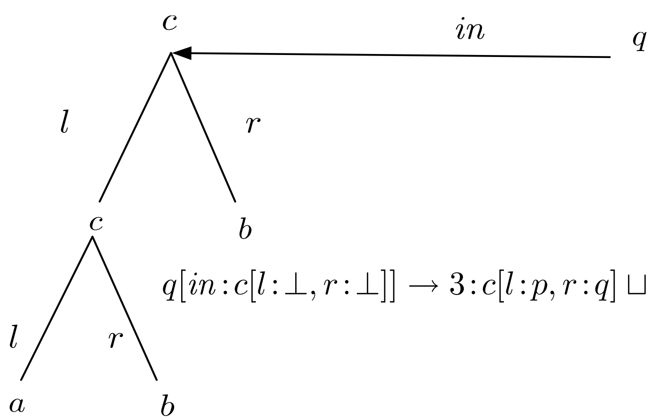
$$n[c\!:\!\bot] \rightarrow \{3\!:\!n[l\!:\!\underline{adj}[c\!:\!\text{pretty}], r\!:\!n[c\!:\!\bot]] \sqcup (c \doteq 3rc),$$
$$3\!:\!\underline{n}[c\!:\!\bot] \sqcup (c \doteq 3c)\}$$

Quick look at tree transductions

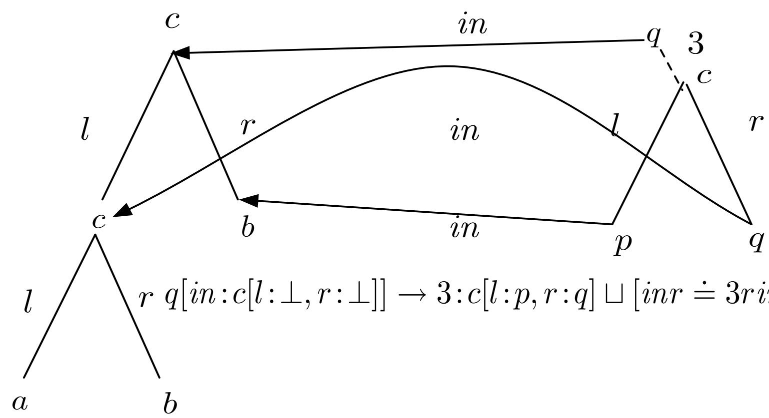


$$q[in\!:\!c[l\!:\!\bot, r\!:\!\bot]] \to 3\!:\!c[l\!:\!p, r\!:\!q] \sqcup [inr \doteq 3lin] \sqcup [inl \doteq 3rin]$$

Quick look at tree transductions

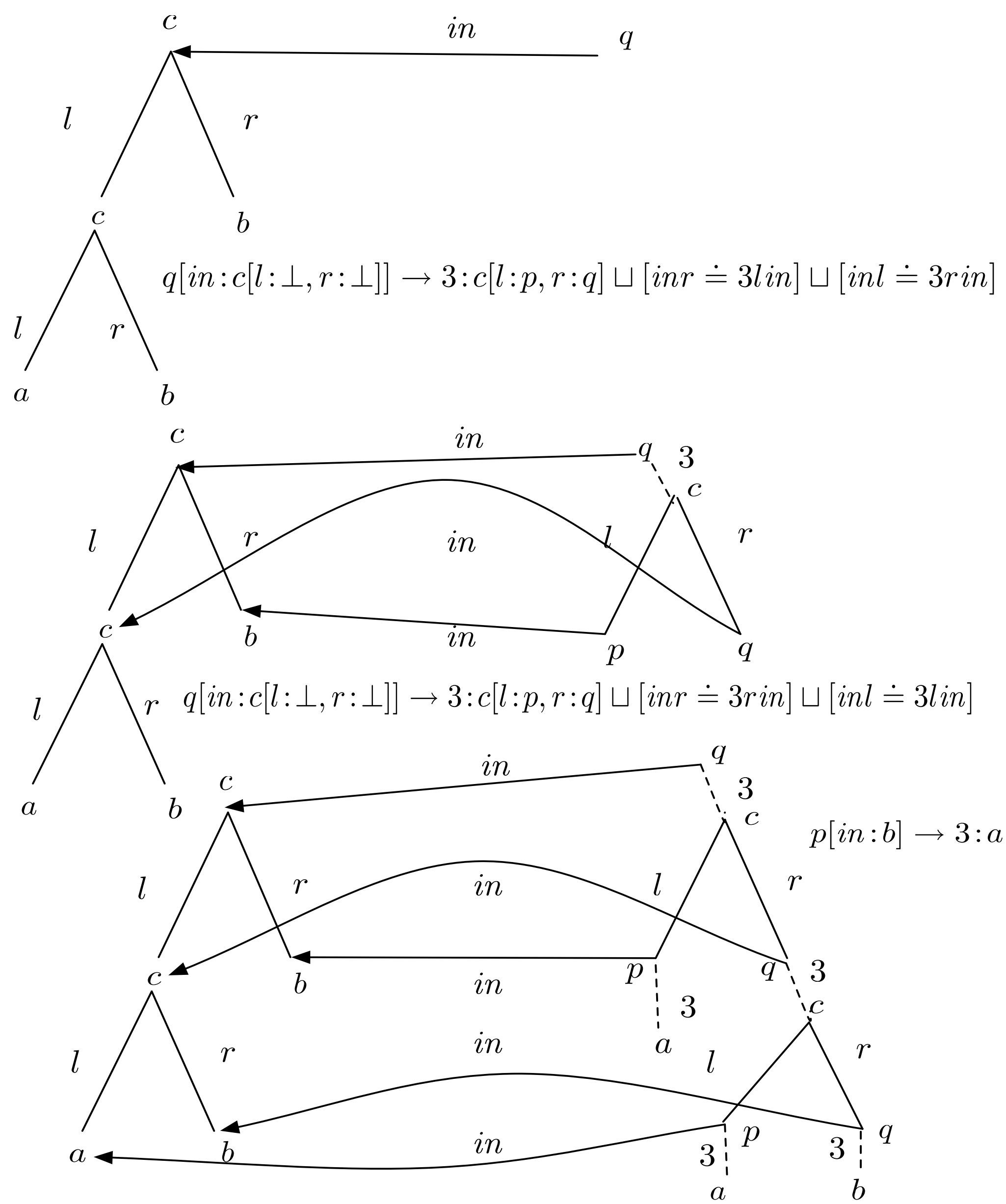


$$q[in\!:\!c[l\!:\!\bot, r\!:\!\bot]] \rightarrow 3\!:\!c[l\!:\!p, r\!:\!q] \sqcup [inr \doteq 3l\,in] \sqcup [inl \doteq 3r\,in]$$



$$q[in\!:\!c[l\!:\!\bot, r\!:\!\bot]] \rightarrow 3\!:\!c[l\!:\!p, r\!:\!q] \sqcup [inr \doteq 3r\,in] \sqcup [inl \doteq 3l\,in]$$

Quick look at tree transductions



Theory behind this

- Disjunctive feature logic programming.
- A program is set of rules of the form $f \to L$, where f is a feature structure, and L is a **clause**, a finite set of feature structures.
- These rules can be used in proofs, to create a **theory**, in general an infinite set of clauses.
- A feature structure m satisfies the clause L if some element of L subsumes it.
- m is a model of the program if for any rule $f \to L$, if f subsumes m, then m satisfies L.
- **Theorem**: the minimal models of the program are the minimal structures satisfying all clauses of the theory.
- This way we can get infinite FS as models.
- There is a sound and complete resolution proof system to go with all of this.

The resolution rules

- Logical resolution:

$$\frac{K \quad L \quad f \in K \quad g \in L \quad f \sqcup g \models M}{M \cup (K \setminus \{f\}) \cup (L \setminus \{g\})}$$

  where K, L, M are clauses.

- Clause introduction (nonlogical resolution):

$$\frac{M \quad g \in M \quad f \rightarrow L \in P \quad f \sqsubseteq g}{L \cup (M \setminus \{g\})}$$

Questions and further work

- Can you compile FL specifications into a parser?
- What about other formalisms, like synchronous TAGS?
- Can you work probabilities, or more generally, weights, into a fully declarative formalism?

Thanks!