Towards Probabilistic Acceptors and Transducers for Feature Structures

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Linguistic structures

Linguistic structures

Strings

surface forms, phonology, morphology

Linguistic structures

Strings

surface forms, phonology, morphology

Trees

syntax

Linguistic structures

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syntax

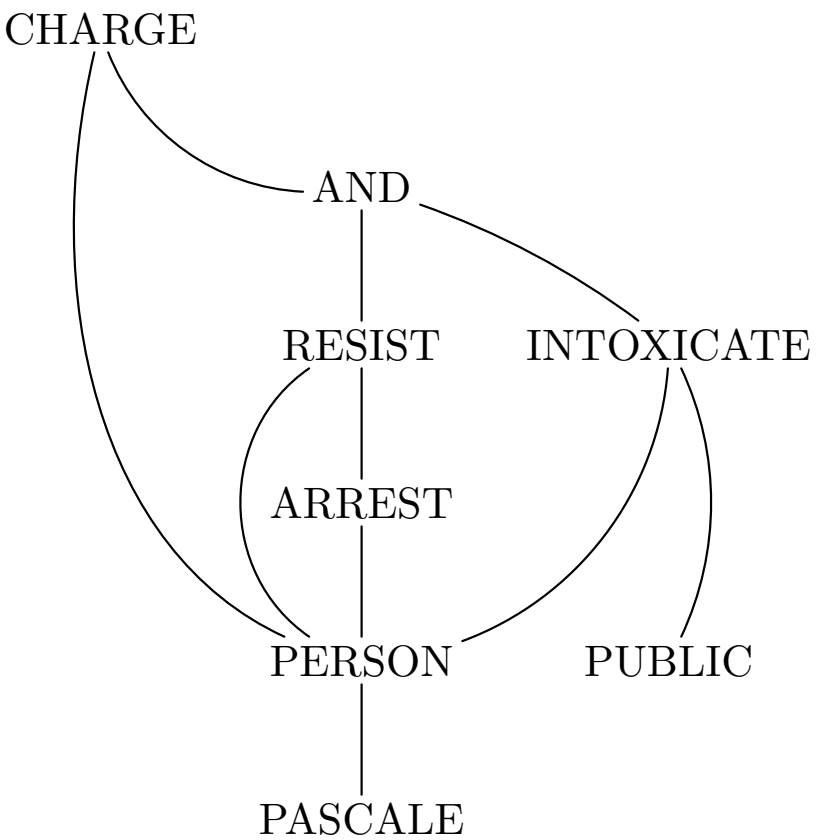
Feature structures (= directed acyclic graphs)

deep syntax (LFG etc.)
semantics (abstract meaning representations)

Feature structures

$$
\begin{bmatrix}
\text{INSTANCE} & \text{charge} \\
\text{THEME} & \boxed{1}\begin{bmatrix}\text{INSTANCE} & \text{person} \\ \text{NAME} & \text{“Pascale”}\end{bmatrix} \\
\text{PRED} & \begin{bmatrix}
\text{INSTANCE} & \text{and} \\
\text{OP1} & \begin{bmatrix}\text{INSTANCE} & \text{resist} \\ \text{AGENT} & \boxed{1} \\ \text{THEME} & \begin{bmatrix}\text{INSTANCE} & \text{arrest} \\ \text{THEME} & \boxed{1}\end{bmatrix}\end{bmatrix} \\
\text{OP2} & \begin{bmatrix}\text{INSTANCE} & \text{intoxicate} \\ \text{THEME} & \boxed{1} \\ \text{LOCATION} & \begin{bmatrix}\text{INSTANCE} & \text{public}\end{bmatrix}\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Directed acyclic graphs



$$\begin{aligned}
\text{CHARGE} &\mapsto \text{charge}(\text{theme}, \text{pred}) \\
\text{AND} &\mapsto \text{and}(\text{op1}, \text{op2}) \\
\text{RESIST} &\mapsto \text{resist}(\text{agent}, \text{theme}) \\
\text{ARREST} &\mapsto \text{arrest}(\text{theme}) \\
\text{INTOXICATE} &\mapsto \text{intoxicate} \\
&\qquad (\text{theme}, \text{location}) \\
\text{PUBLIC} &\mapsto \text{public}() \\
\text{PERSON} &\mapsto \text{person}(\text{name}) \\
\text{PASCALE} &\mapsto \text{"Pascale"}
\end{aligned}$$

Translation pipelines

Syntax-based MT pipeline

$$\text{fstring} \rightarrow \boxed{\text{translate}} \rightarrow \text{etree} \rightarrow \boxed{\text{language model}} \rightarrow \text{estring}$$

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- The individual components are efficiently represented as **weighted tree acceptors and transducers**.

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Syntax-based MT pipeline

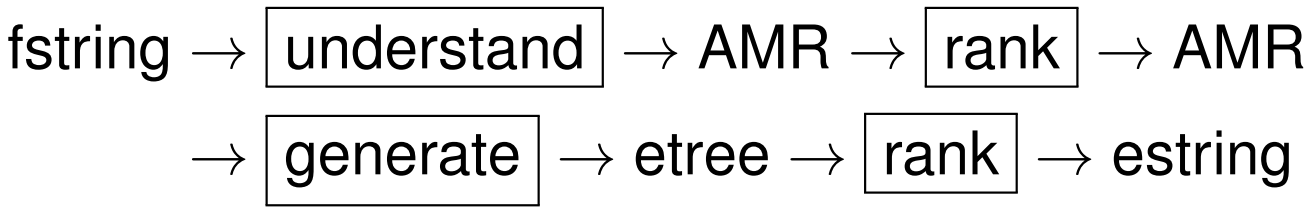
$$\underset{\text{fstring}}{\text{FSA}} \rightarrow \boxed{\underset{\text{translate}}{\text{nl-XTOPs}^{-1}}} \rightarrow \underset{\text{etree}}{\text{RTG}} \rightarrow \boxed{\underset{\text{language model}}{\text{FSA}}} \rightarrow \underset{\text{estring}}{\text{FSA}}$$

- The individual components are efficiently represented as **weighted tree acceptors and transducers**.

$$\text{estring} = \textsc{BestPath}(\textsc{Intersect}(\text{language model}, \textsc{Yield}(\textsc{Backwards}(\text{translate}, \text{fstring})))).$$

Translation pipelines (2)

Semantics-based MT pipeline



Translation pipelines (2)

Semantics-based MT pipeline

$$\text{fstring} \rightarrow \boxed{\text{understand}} \rightarrow \text{AMR} \rightarrow \boxed{\text{rank}} \rightarrow \text{AMR}$$
$$\rightarrow \boxed{\text{generate}} \rightarrow \text{etree} \rightarrow \boxed{\text{rank}} \rightarrow \text{estring}$$

- No suitable automaton framework is known!

Algorithms and automata

	string automata	tree automata	graph automata
k-best	paths through a WFSA	trees in a weighted forest	
EM training	Forward-backward EM	Tree transducer EM training	
Determinization	of weighted string acceptors	of weighted tree acceptors	
Transducer composition	WFST composition	Many transducers not closed under composition	
General tools	AT&T FSM, Carmel, OpenFST	Tiburon	

Table: General-purpose algorithms for strings, trees and feature structures.

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- Find an adequate automaton model for the pipeline parts
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- Unification grammars (HPSG, LFG) (too powerful?)
- Hyperedge replacement grammar (too powerful?)
- Some straightforward extension of string/tree automata?

Dag automata

finite string automaton: (FSA)

one input state, one input symbol, one output state

$$\cdots \quad p \text{——} \sigma \text{——} q \quad \cdots$$

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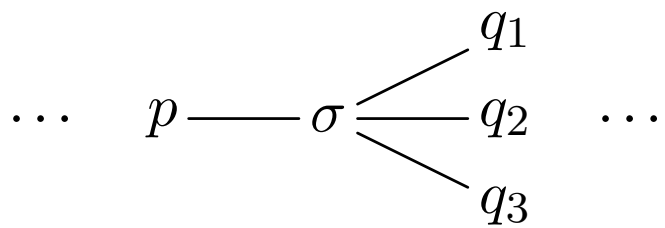

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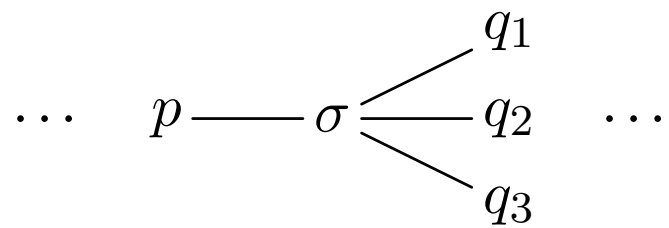
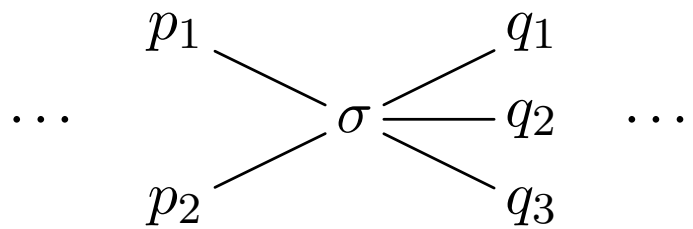


finite dag automaton: (FDA?)

many input states, one input symbol, many output states



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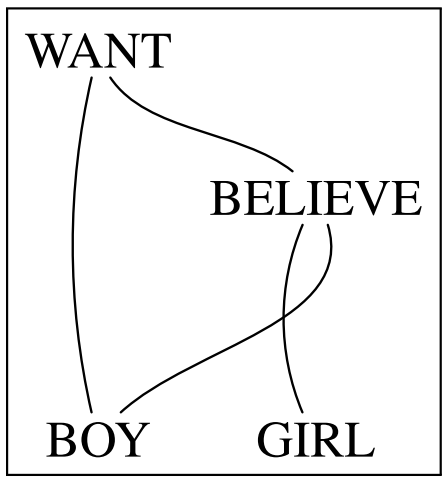

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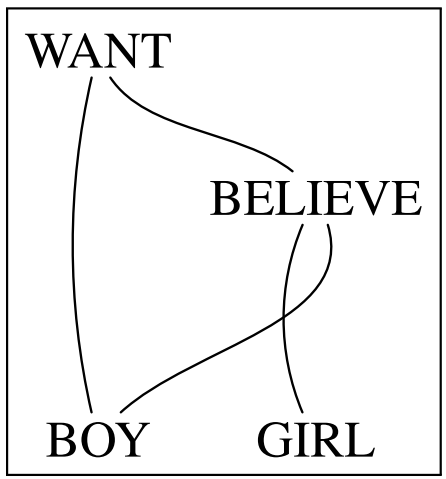
- Dag acceptors and dag-to-tree transducers
- They proved a couple of technical properties, no algorithms
- We investigate their model with some adjustments:
  - not only adjacent leaves can be connected
  - top-down transducers instead of bottom-up
  - we introduce weights (probabilities)



Example dag automaton

$$
\begin{aligned}
q &\rightarrow \textsc{want}(r, q)\langle 0.3\rangle \\
q &\rightarrow \textsc{believe}(r, q)\langle 0.2\rangle \\
q &\rightarrow r\,\langle 0.4\rangle \mid \emptyset\,\langle 0.1\rangle \\
r &\rightarrow \textsc{boy}\langle 0.3\rangle \mid \textsc{girl} \\
&\quad\ \langle 0.3\rangle \mid \emptyset\,\langle 0.1\rangle \\
[r, r] &\rightarrow r\,\langle 0.2\rangle \\
[r, r, r] &\rightarrow r\,\langle 0.1\rangle
\end{aligned}
$$

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\textsc{want} &\mapsto \mathsf{want}(\mathsf{agent}, \mathsf{theme}) \\
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Example dag generation

q

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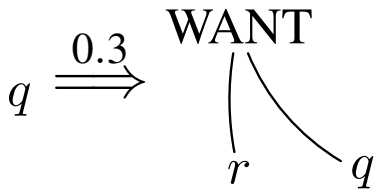

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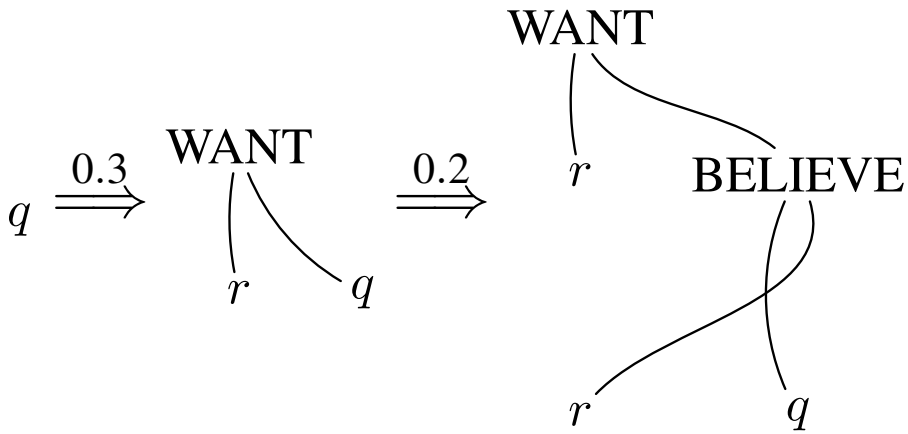

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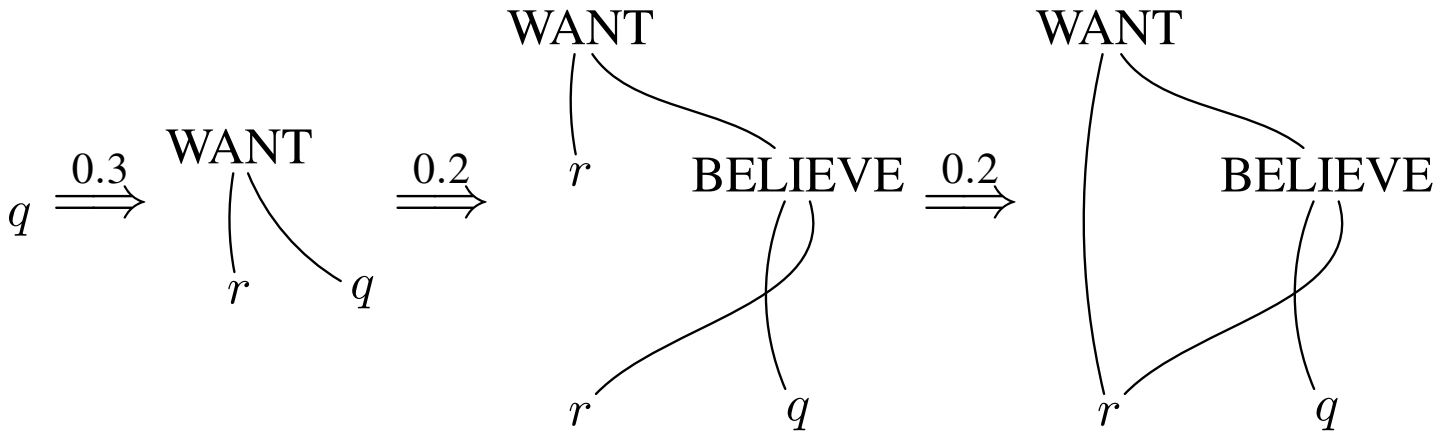

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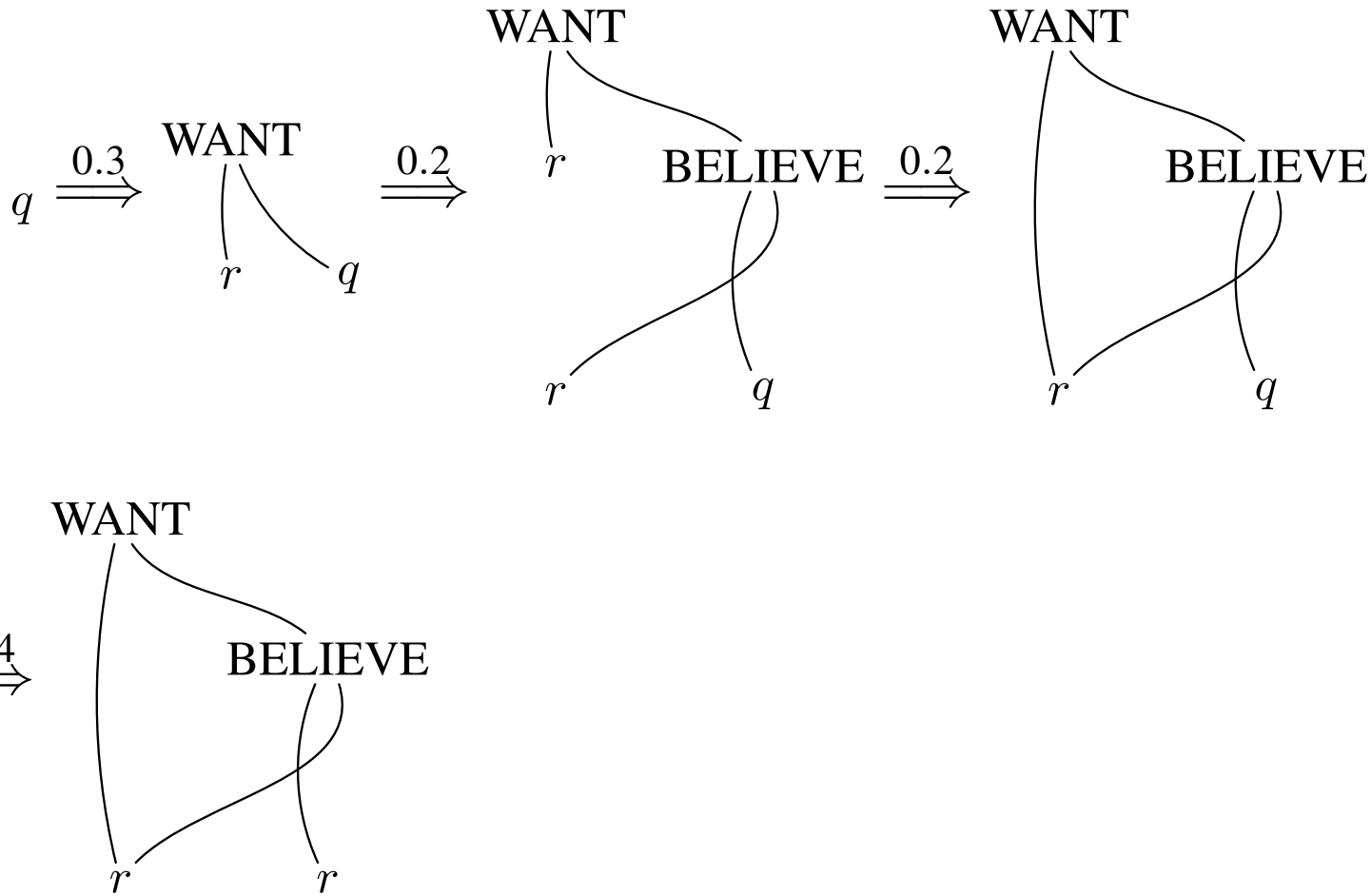

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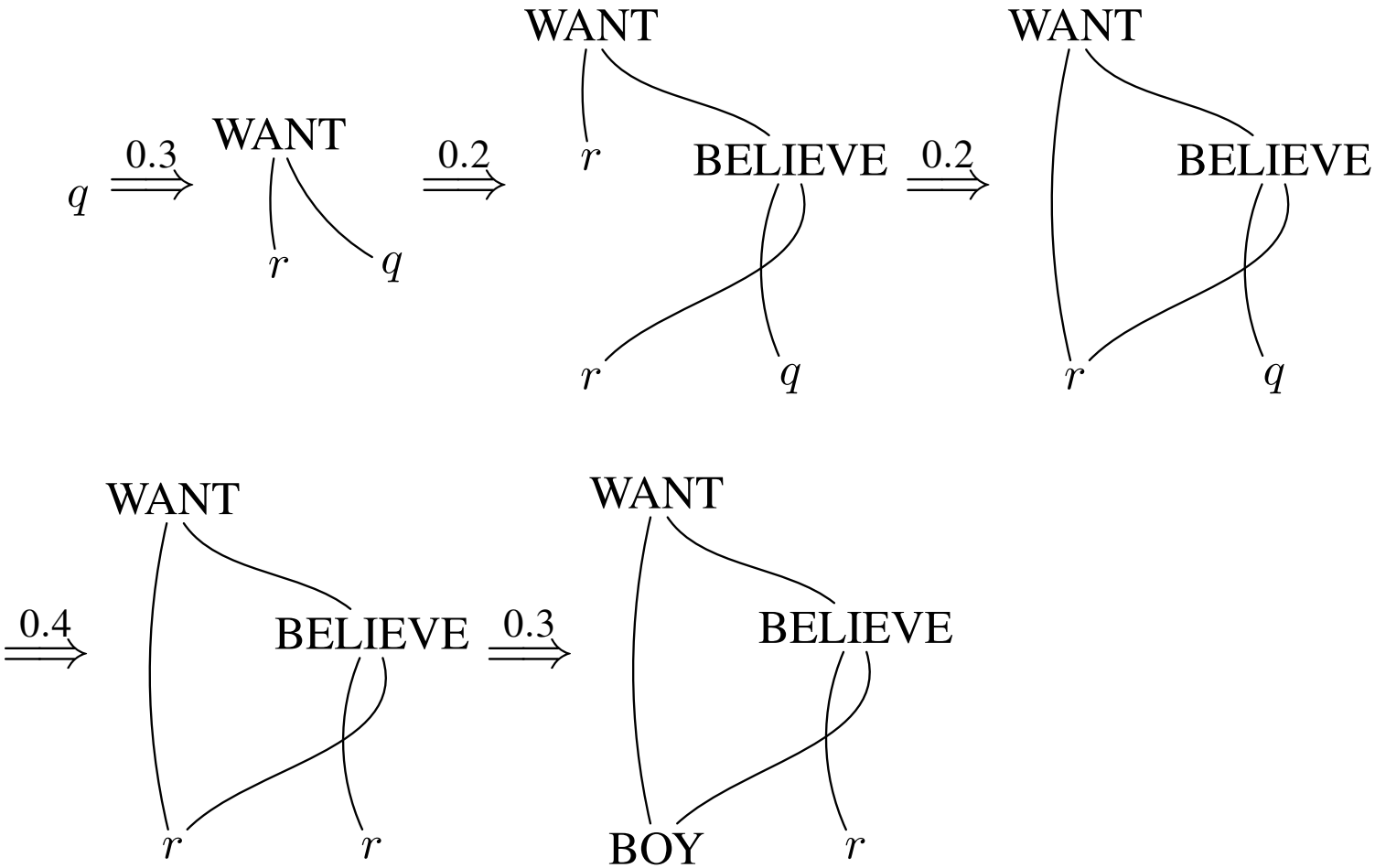

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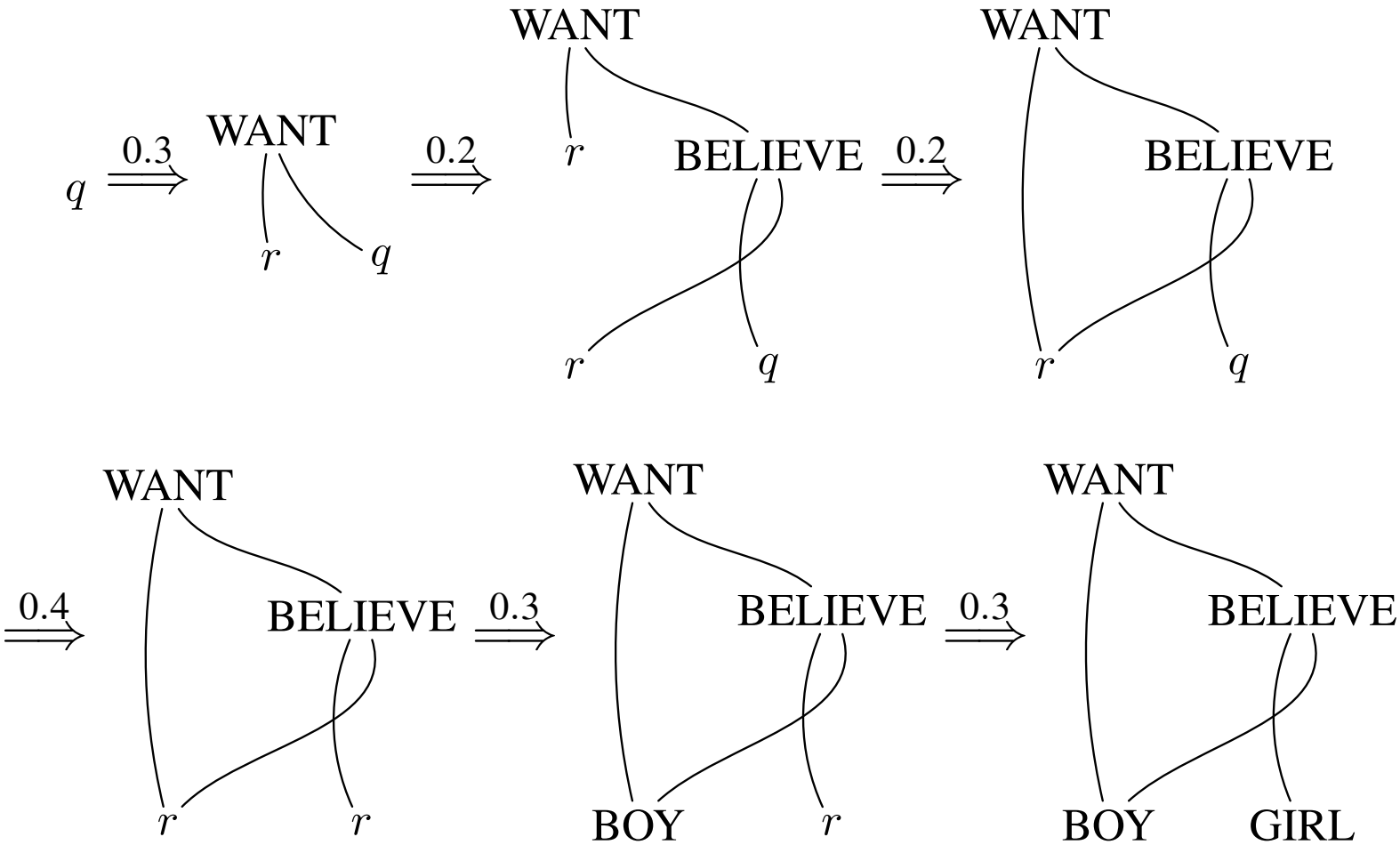

Example dag transducer rules

- Rules have m incoming edges with states and produce m trees

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$$[q_{nomb}, q_{accb}].\text{BOY} \rightarrow \text{NP(the boy)}, \text{NP(him)}$$
$$q_{accg}.\text{GIRL} \rightarrow \text{NP(the girl)}$$

Example dag transducer rules

- Rules have m incoming edges with states and produce m trees
- Rules have n outgoing edges and n variables to pass states down

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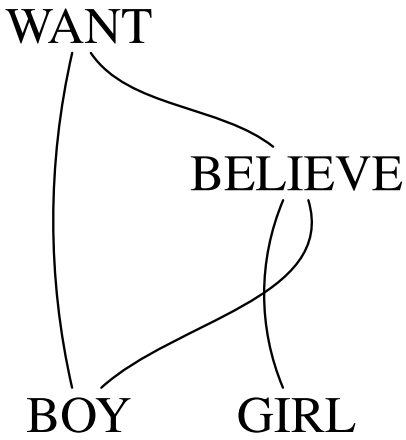
$$q_{accg}.\text{GIRL} \rightarrow \text{NP(the girl)}$$

$$q_s.\text{WANT}(x, y) \rightarrow \text{S}(q_{nomb}.x, \text{wants}, q_{infb}.y)$$
$$q_{infb}.\text{BELIEVE}(x, y) \rightarrow \text{INF}(q_{accg}.x, \text{to believe}, q_{accb}.y)$$

Example dag transduction



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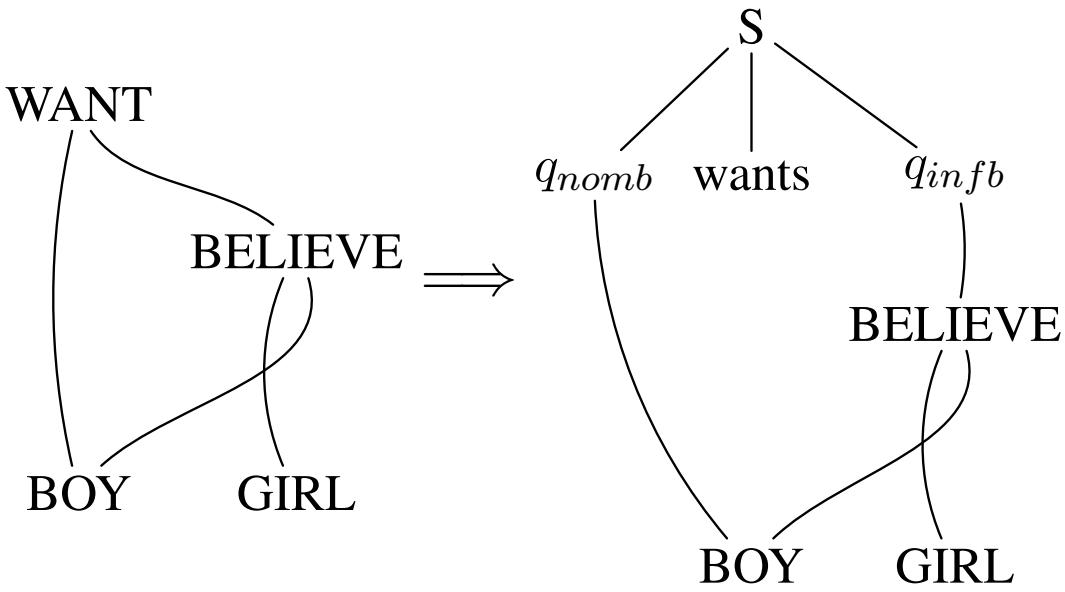

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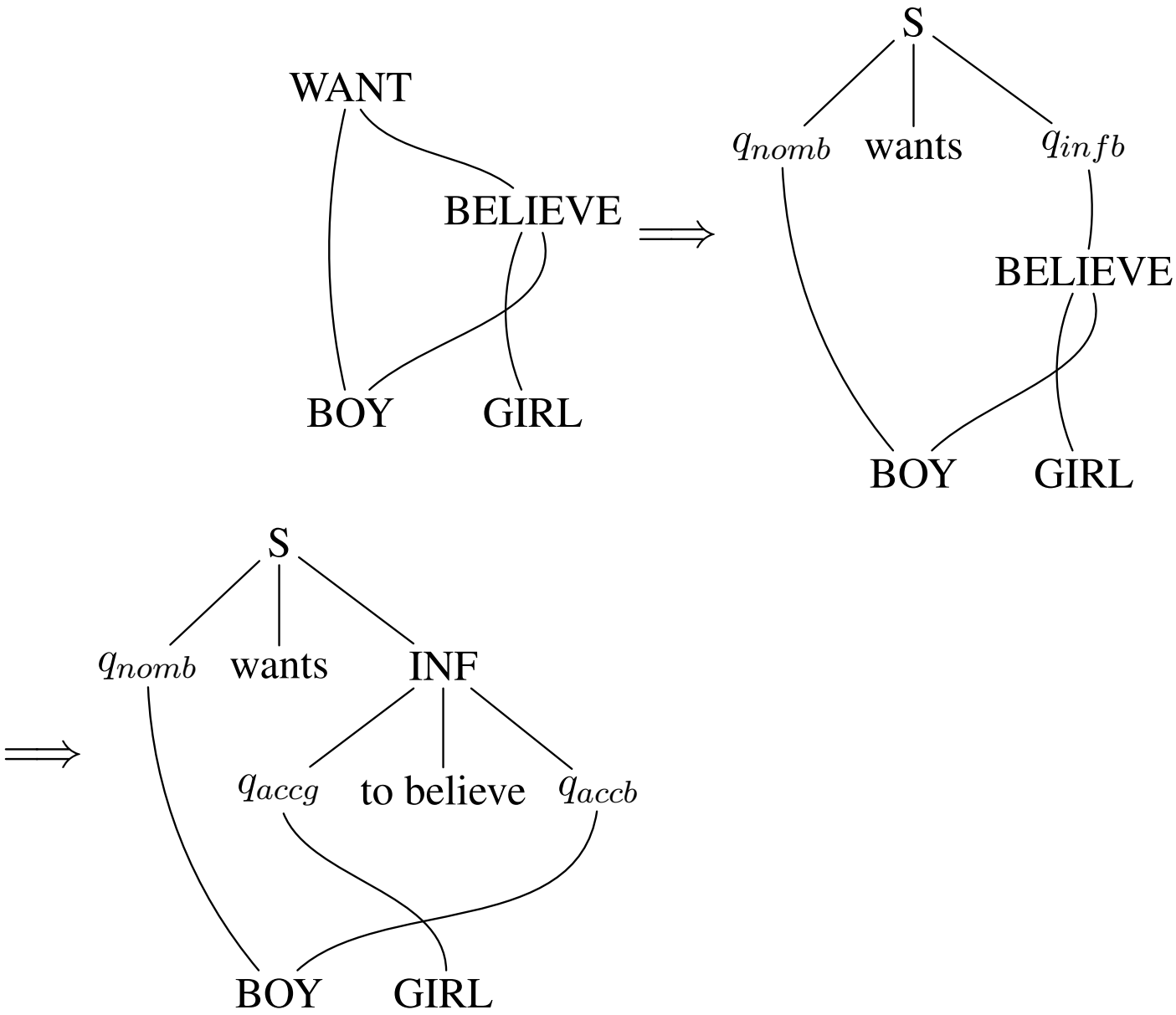

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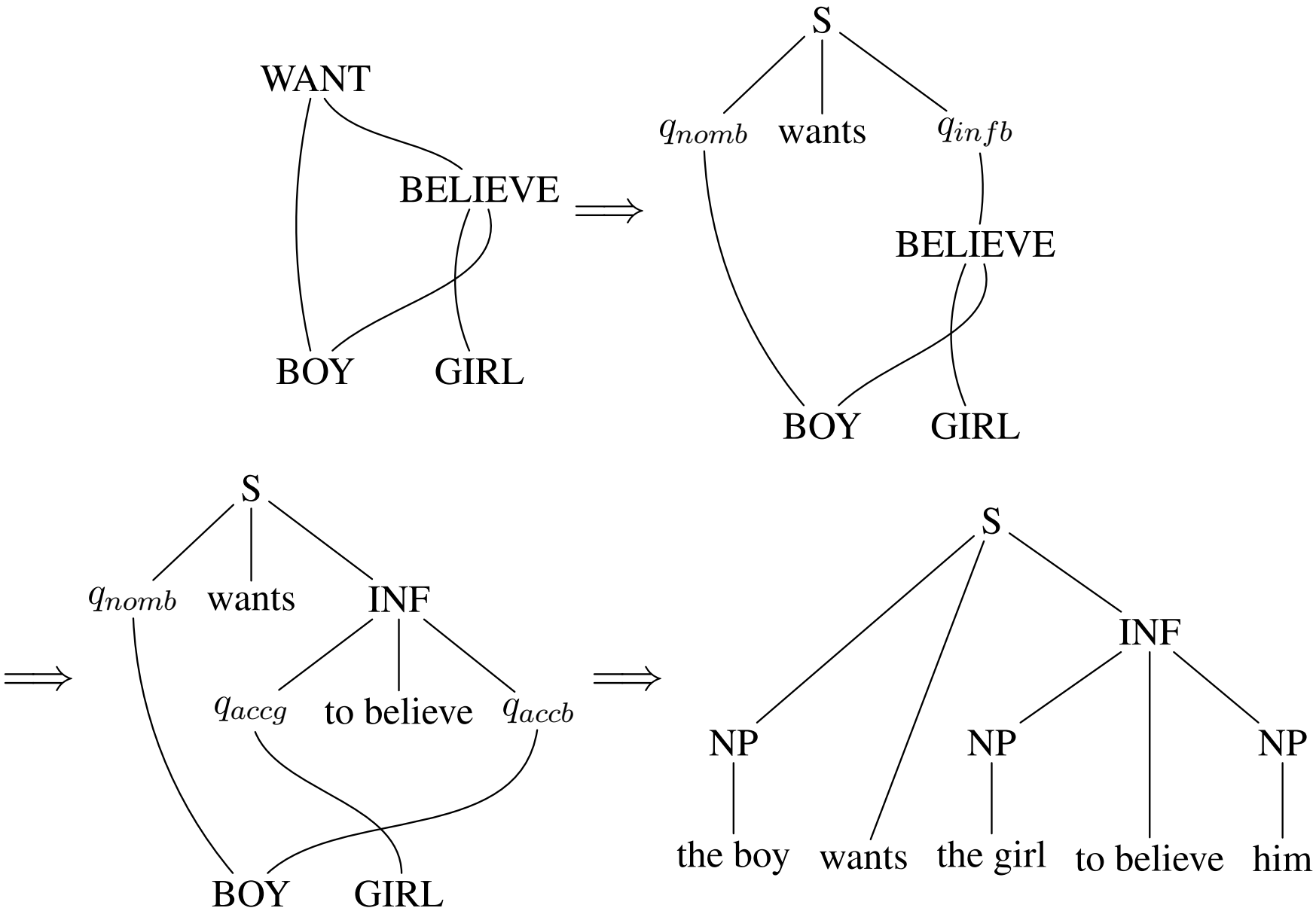

What's it for?

What's wrong with phrase-based and syntax-based MT?

- We want the "**who did what to whom, when, where, and why**"
- Preservation of meaning can be more important than grammaticality/fluency
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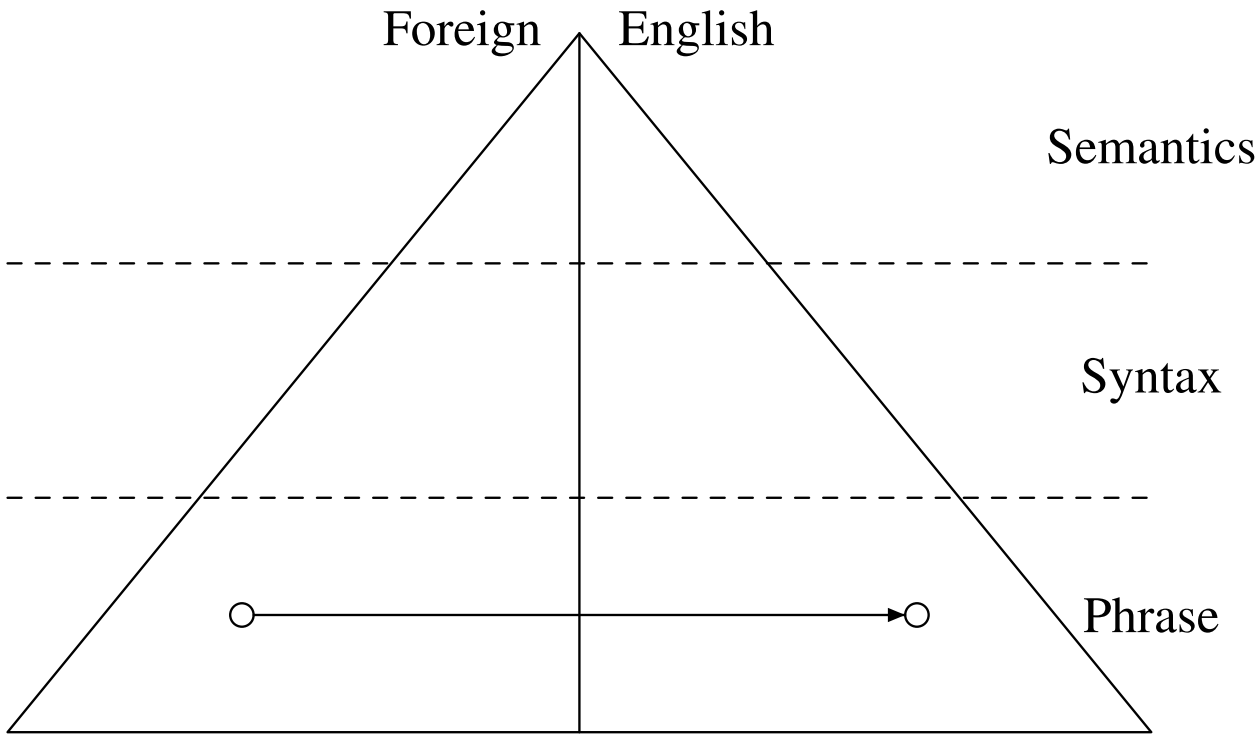
Yes, but...

- that was before **statistics**
- small-scale, hand-crafted
- people said the same about syntax-based MT and look where it's now!

Different MT paradigms



phrase-based MT: n-grammatical

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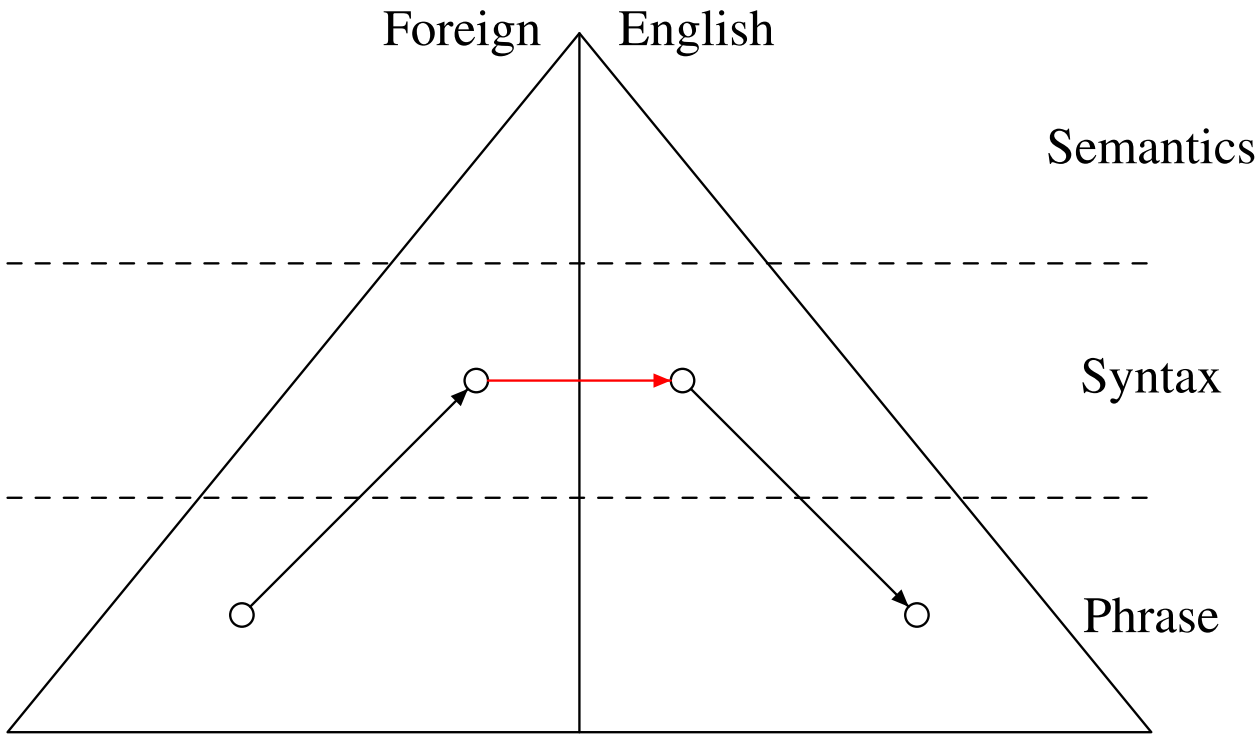

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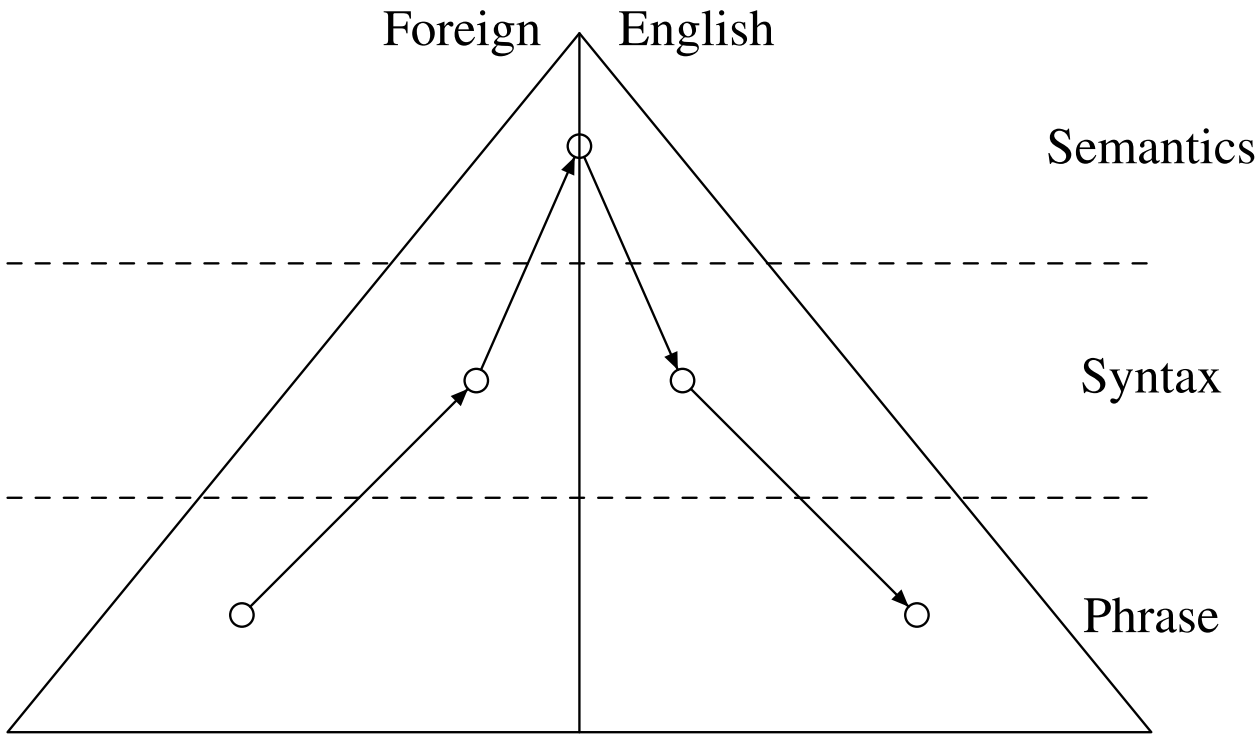

phrase-based MT: n-grammatical

syntax-based MT: grammatical

semantics-based MT: **sensible** and grammatical

Building an NLP system

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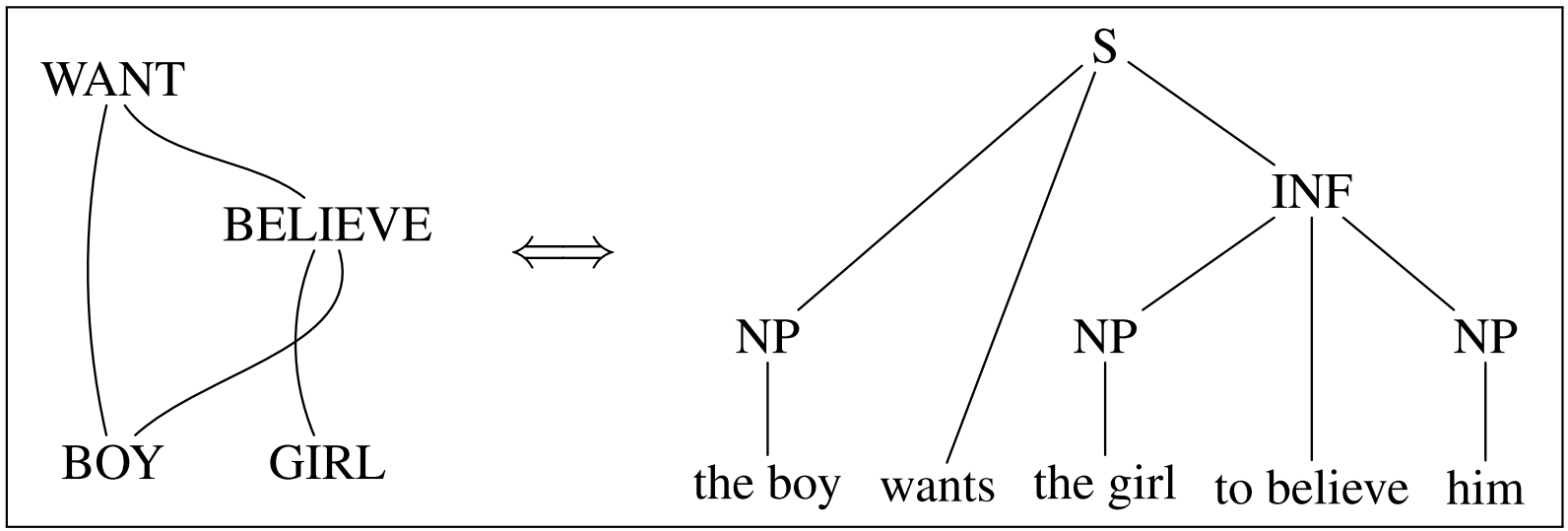

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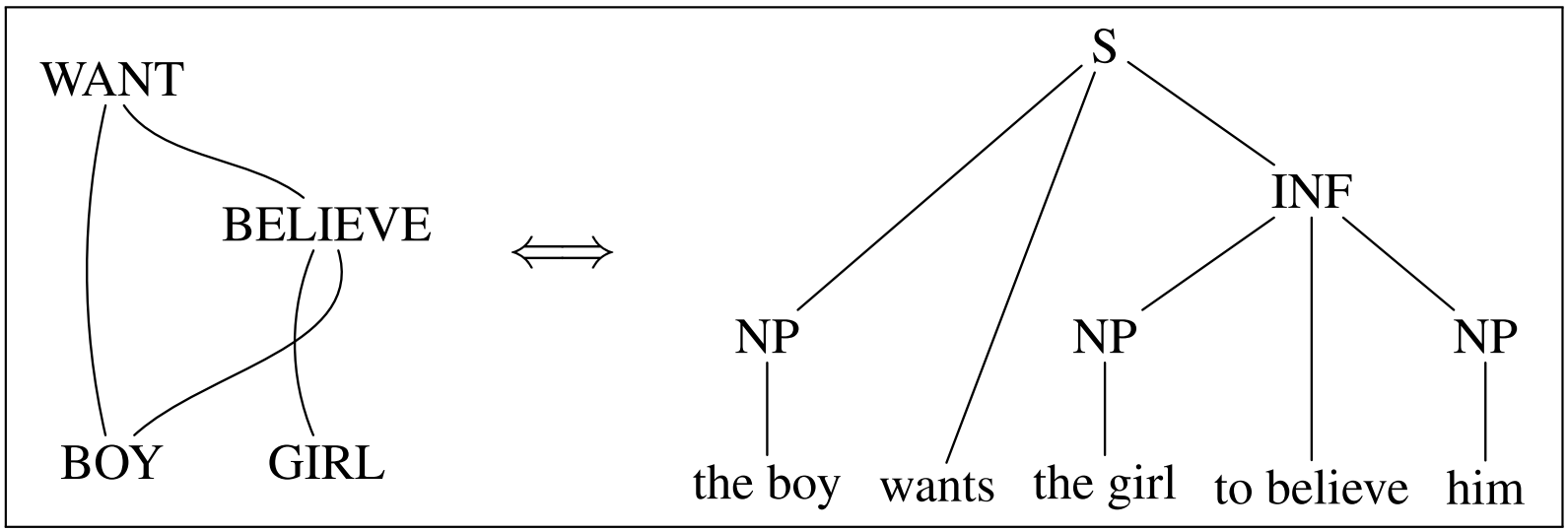

- Train models for parts of the translation pipeline
- Use them in a bucket-brigade approach or in an integrated decoder

Toolkit (FSMNLP 2012)

We implemented (in Python):

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- **visualization** of trees and graphs using GraphViz

Future work

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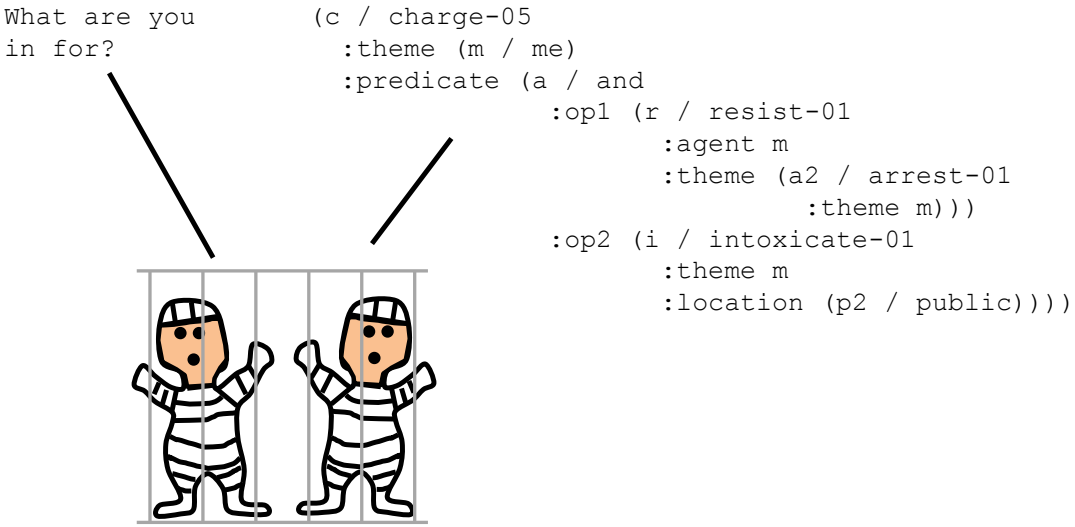
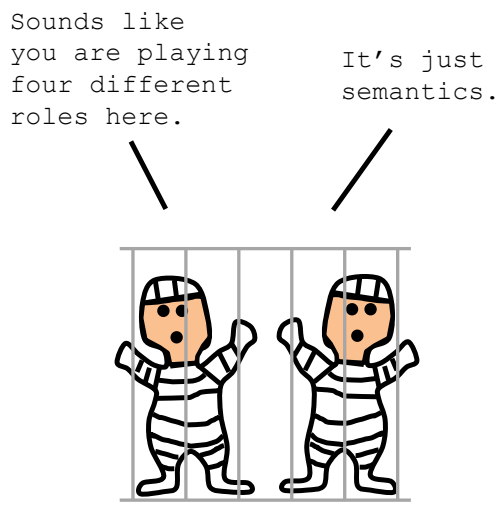
Download

`http://www.ims.uni-stuttgart.de/~daniel/dagger/`

The ~~end~~ beginning

Thank you for your attention! – Questions?





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