Glue semantics for Universal Dependencies

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  - dependency structures $\approx$ f-structures
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  - LFG inheritance in UD (via Stanford dependencies)
  - Glue offers a syntax-semantics interace where syntax can underspecify semantics
- Postpone the need for language-specific, lexical resources

Outline

Plan

Target representations

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- We assume discourse referents (drefs) of three sorts: entities (x_n), eventualities (e_n) and propositions (p_n).
- The predicate *ant* means that its argument has an antecedent (it's a presupposed dref).

  $\rightarrow$ Also applies to the predicates beginning *pron.*_
- The connective ∂ marks presupposed conditions—it maps TRUE to TRUE and is otherwise undefined.

  $\rightarrow$ Unlike Boxer, which has separate DRSs for presupposed and asserted material.

An example

(1) Abrams persuaded the dog to bark.

Boxer:

$$\left(\begin{array}{|l|}\hline x_2 \\ \hline dog(x_2) \\ \hline \end{array} + \begin{array}{|l|}\hline x_1\ e_1\ p_1 \\ \hline named(x_1, abrams) \\ persuade(e_1) \\ agent(e_1, x_1) \\ theme(e_1, x_2) \\ content(e_1, p_1) \\ p_1 : \begin{array}{|l|}\hline e_2 \\ \hline bark(e_2) \\ agent(e_2, x_2) \\ \hline \end{array} \\ \hline \end{array}\right)$$

Us:

$$\begin{array}{|l|}\hline x_1\ x_2\ e_1\ p_1 \\ \hline named(x_1, abrams) \\ ant(x_2) \\ \partial(dog(x_2)) \\ persuade(e_1) \\ agent(e_1, x_1) \\ theme(e_1, x_2) \\ content(e_1, p_1) \\ p_1 : \begin{array}{|l|}\hline e_2 \\ \hline bark(e_2) \\ agent(e_2, x_2) \\ \hline \end{array} \\ \hline \end{array}$$

Other running examples

(taken from the CCS development suite)

(2) He hemmed and hawed.

x_1 e_1 e_2
$pron.he(x_1)$ $hem(e_1)$ $agent(e_1, x_1)$ $haw(e_2)$ $agent(e_2, x_1)$

(3) The dog they thought we admired barks.

$x_1\ x_2\ x_3\ e_1\ e_2\ p_1$
$ant(x_1), \partial(dog(x_1))$ $pron.they(x_2), pron.we(x_3)$ $bark(e_1), agent(e_1, x_1)$ $\partial(think(e_2)), \partial(agent(e_2, x_2))$ $\partial(content(e_2, p_1))$ p_1 : [(no referents) | $admire(e_3)$, $agent(e_3, x_3)$, $theme(e_3, x_1)$]

Underlying logic

- The Glue approach relies on meanings being put together by application and abstraction, so we need some form of compositional or λ-DRT for meaning construction.

$$\text{someone} \rightsquigarrow \lambda P.\boxed{\begin{array}{l} x_1 \\ \hline \mathit{person}(x_1) \end{array}} \;;\; P(x_1)$$

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$$\text{someone} \leadsto \lambda P.\begin{array}{|c|}\hline x_1 \\ \hline person(x_1) \\ \hline \end{array} \; ; \; P(x_1)$$

- Conceptually, we are assuming PCDRT (Haug, 2014), which has a definition of the *ant* predicate and (relatedly) a treatment of so-far-unresolved anaphora that doesn't require indexing.
- This specific assumption is not crucial, though.

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> *A crude characterisation would be that glue semantics is like categorial grammar and its semantics, but without the categorial grammar.*
>
> (Crouch & van Genabith, 2000, 91)

Scope ambiguity as an example

(4) Someone sees everything.

Two interpretations:

1. There is someone who sees everything. (surface scope, $\exists > \forall$)
2. Everything is seen. (inverse scope, $\forall > \exists$)

Q: Where is the ambiguity?

Montague Grammar
(Montague, 1973; Dowty et al., 1981)

Ambiguity of syntactic derivation:

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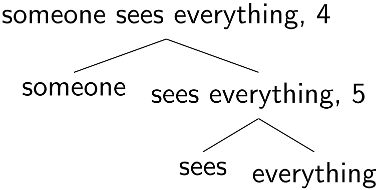
Surface scope



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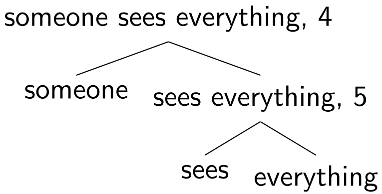
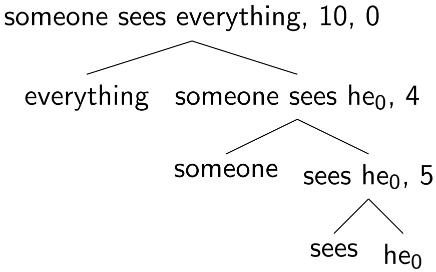


Inverse scope



Mainstream Minimalism

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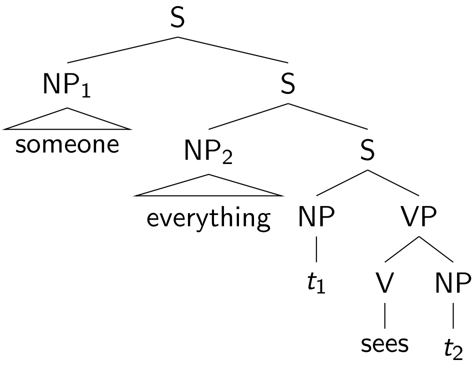

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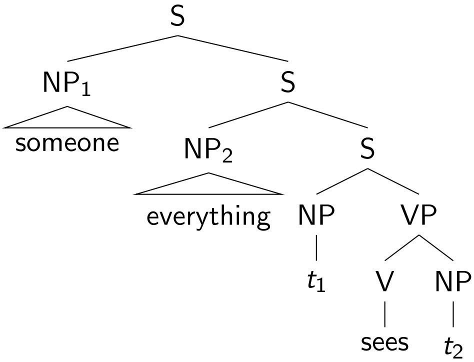

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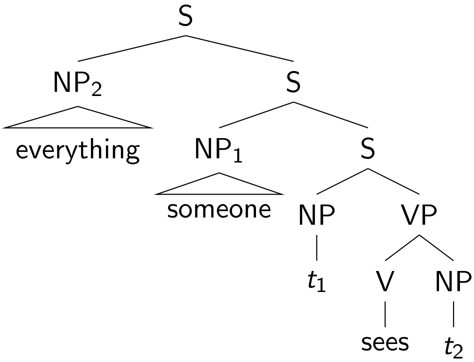

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- The approaches just mentioned have in common is the view that syntactic structure plus lexical semantics *determines* interpretation.
- From this it follows that if a sentence is ambiguous, such as (4), then that ambiguity must be either lexical or syntactic.
- The Glue approach is that syntax *constrains* what can combine with what, and how.

  (to this extent there is a similarity with Cooper storage (Cooper, 1983))

- Totally informal statement of what the constraints look like in (4):

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  - ⟦*sees*⟧ applies to A, then B, to form C.
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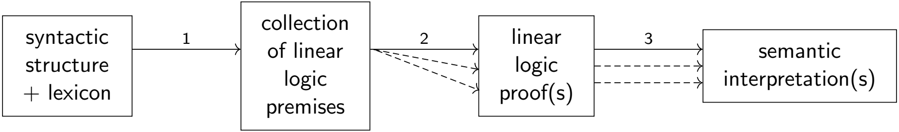
- There's more than one way to put ⟦*someone*⟧, ⟦*sees*⟧ and ⟦*everything*⟧ together, while obeying these constraints, to form C.
- The different ways:
  - Give the different interpretations of (4).
  - Correspond to different proofs from the same premises in Linear Logic.

The syntax-semantics interface according to Glue



1. Function, given by Glue implementation
2. Relation, given by linear logic proof theory
3. Function, given by Curry-Howard correspondence

Linear logic

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to be valid, every premise in premise(s) must be 'used' exactly once. So for example,

$$\begin{array}{lll} A \vdash A & \text{and} & A, A \multimap B \vdash B, \text{ but} \\ A, A \nvdash A & \text{and} & A, A \multimap (A \multimap B) \nvdash B \end{array}$$

($\multimap$ is linear implication)

Interpretation as deduction

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- expressions of a meaning language (in this case, λ-DRT) are paired with formulae in a fragment of linear logic (the glue language), and
- steps of deduction carried out using those formulae correspond to operations performed on the meaning terms, according to the Curry-Howard correspondence.

Linear implication

Rules for $\multimap$	
Elimination...	Introduction...
$$\frac{X \multimap Y \qquad X}{Y} \multimap_E$$	$$\frac{\begin{array}{c}[X]^n \\ \vdots \\ Y\end{array}}{X \multimap Y} \multimap_{I,n}$$ Exactly one hypothesis must be discharged in the introduction step.

Linear implication and functional types

Rules for $\multimap$ and their images under the Curry-Howard correspondence		
Elimination...	Introduction...	
$$\frac{f : X \multimap Y \quad a : X}{f(a) : Y} \multimap_E$$	$$\frac{\begin{matrix}[v : X]^n \\ \vdots \\ f : Y\end{matrix}}{\lambda v.f : X \multimap Y} \multimap_{I,n}$$	Exactly one hypothesis must be discharged in the introduction step.
... corresponds to ...		
... application.	... abstraction.	

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...application.	...abstraction.	

Propositions as types:

$$type(X \multimap Y) := type(X) \rightarrow type(Y)$$

What you need from syntax

label	A	B	C
assigned to	the object argument of *sees*	the subject argument of *sees*	the sentence as a whole
	everything	*someone*	(where *someone* takes scope)
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$$\Downarrow$$

$\lambda Q.[x_1 \mid person(x_1)]; Q(x_1) : (B \multimap C) \multimap C$ type $(e \to t) \to t$

$\lambda v.\lambda u.[\ \mid see(u, v)] : A \multimap (B \multimap C)$ type $e \to (e \to t)$

$\lambda P.[\ \mid [x_1 \mid\ ] \Rightarrow P(x_1)] : (A \multimap C) \multimap C$ type $(e \to t) \to t$

Surface scope interpretation

$$\dfrac{\begin{array}{c}[\![someone]\!]:\\(B\multimap C)\multimap C\end{array} \quad \dfrac{\dfrac{\begin{array}{c}[\![everything]\!]:\\(A\multimap C)\multimap C\end{array}\quad \dfrac{\dfrac{\dfrac{\begin{array}{c}[\![sees]\!]:\\A\multimap(B\multimap C)\end{array}\quad [z:A]^1}{[\![sees]\!](z):B\multimap C}\multimap_E \quad [w:B]^2}{[\![sees]\!](z)(w):C}\multimap_E}{\lambda z.[\![sees]\!](z)(w):A\multimap C}\multimap_{I,1}}{[\![everything]\!](\lambda z.[\![sees]\!](z)(w)):C}\multimap_E}{\lambda w.[\![everything]\!](\lambda z.[\![sees]\!](z)(w)):B\multimap C}\multimap_{I,2}}{[\![someone]\!](\lambda w.[\![everything]\!](\lambda z.[\![sees]\!](z)(w))):C}\multimap_E$$

$$\leadsto_\beta \begin{array}{|l|}\hline x_1\\\hline person(x_1)\\ \begin{array}{|c|}\hline x_2\\\hline \\\hline\end{array} \Rightarrow \begin{array}{|c|}\hline \\\hline see(x_1,x_2)\\\hline\end{array}\\\hline\end{array}$$

Inverse scope interpretation

$$
\dfrac{
 \begin{array}{c}[\![\mathit{everything}]\!] : \\ (A \multimap C) \multimap C\end{array}
 \quad
 \dfrac{\dfrac{\begin{array}{c}[\![\mathit{someone}]\!] : \\ (B \multimap C) \multimap C\end{array} \quad \dfrac{\begin{array}{c}[\![\mathit{sees}]\!] : \\ A \multimap (B \multimap C)\end{array} \quad [z : A]^1}{[\![\mathit{sees}]\!](z) : B \multimap C}\multimap_E}{[\![\mathit{someone}]\!]([\![\mathit{sees}]\!](z)) : C}\multimap_E}{\lambda z.[\![\mathit{someone}]\!]([\![\mathit{sees}]\!](z)) : A \multimap C}\multimap_{I,1}
}{[\![\mathit{everything}]\!](\lambda z.[\![\mathit{someone}]\!]([\![\mathit{sees}]\!](z))) : C}\multimap_E
$$

$$
\rightsquigarrow_\beta
\begin{array}{|c|}
\hline
\\
\hline
\begin{array}{|c|}\hline x_1 \\ \hline \\ \hline\end{array}
\Rightarrow
\begin{array}{|l|}\hline x_2 \\ \hline \mathit{person}(x_2) \\ \mathit{see}(x_2, x_1) \\ \hline\end{array}
\\
\hline
\end{array}
$$

Plan

Theoretical considerations

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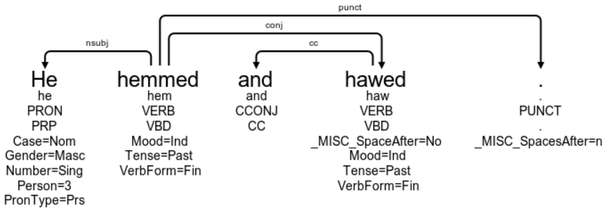
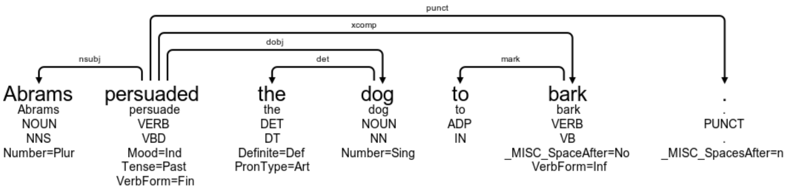
- Dependency grammars have severe expressivity constraints
  - Unique head constraint
  - Overt token constraint
- There are also some UD-specific choices
  - No argument/adjunct distinction
- Some of this will be alleviated through enhanced dependencies but those are not yet widely available

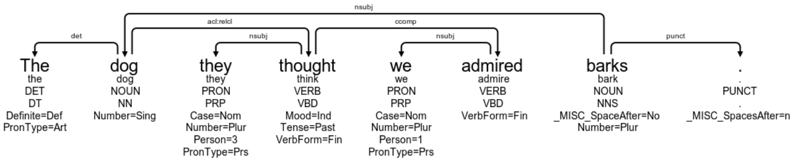
Coordination structure



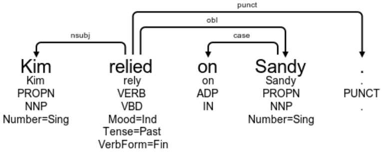
Control structure

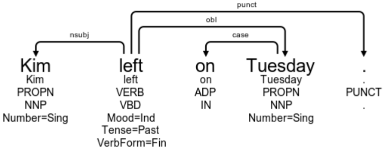


Relative clause structure



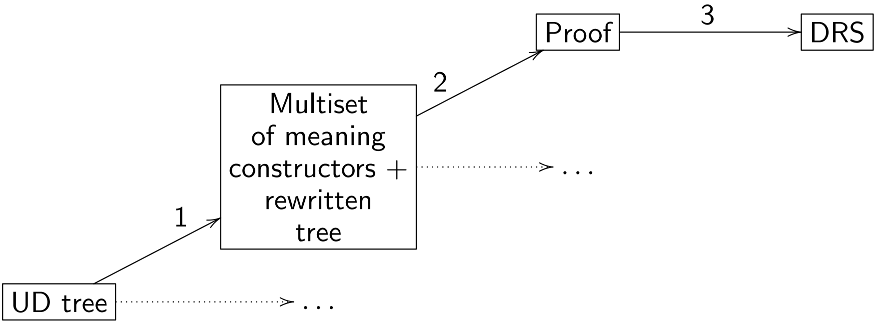
No argument/adjunct distinction





Plan

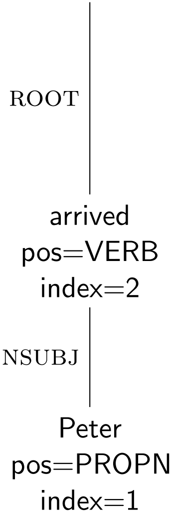
Overview


UD tree
1
Multiset of meaning constructors + rewritten tree
. . .
2
Proof
3
DRS
. . .

Overview

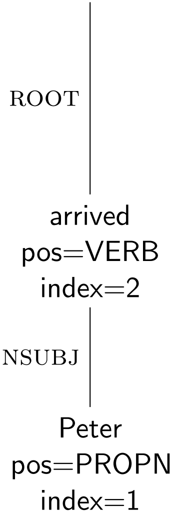
- Traversal of the UD tree, matching each node against a rule file
- For each matched rule, a meaning constructor is produced...
- ...and then instantiated non-deterministically, possibly rewriting the UD tree in the process
- The result is a set of pairs $\langle M, T \rangle$ where M is a multiset of meaning constructors and T is a rewritten UD tree
- Each multiset is fed into a linear logic prover (by Miltiadis Kokkonidis) and beta reduction software (from Johan Bos' Boxer)

Example



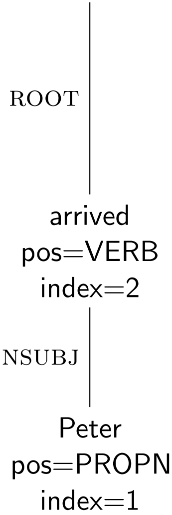
$$\text{pos} = \text{PROPN} \rightarrow$$
$$\lambda P.[x|\mathit{named}(x, \mathit{:lemma:})]\ ;\ P(x) :$$
$$(e_{\downarrow} \multimap t_{\%R}) \multimap t_{\%R}$$

Example



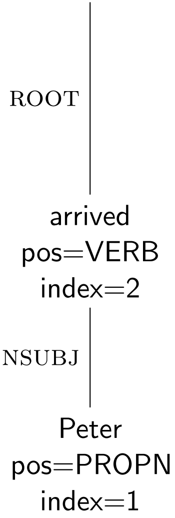
$$\text{pos} = \text{PROPN} \rightarrow$$
$$\lambda P.[x|named(x, Peter)]\ ;\ P(x) :$$
$$(e_1 \multimap t_2) \multimap t_2$$

Example



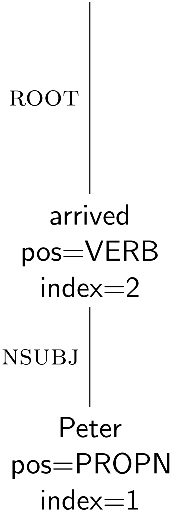
$$\text{pos} = \text{VERB} \rightarrow$$
$$\lambda F, [e | \mathit{:lemma:}(e)]; \mathit{:DEP:}(e); F(e) :$$
$$(v_{\downarrow} \multimap t_{\downarrow}) \multimap t_{\downarrow}$$

Example



$$\text{pos} = \text{VERB} \rightarrow$$
$$\lambda x.\lambda F, [e|arrive(e), nsubj(e, x)] ; F(e) :$$
$$e_{\downarrow nsubj} \multimap (v_{\downarrow} \multimap t_{\downarrow}) \multimap t_{\downarrow}$$

Example



$$\text{pos} = \text{VERB} \rightarrow$$
$$\lambda x.\lambda F, [e|\mathit{arrive}(e), \mathit{nsubj}(e,x)] \; ; F(e) :$$
$$e_1 \multimap (v_2 \multimap t_2) \multimap t_2$$

Example

ROOT

arrived
pos=VERB
index=2

NSUBJ

Peter
pos=PROPN
index=1

relation = ROOT $\rightarrow$
$\lambda\_.[\ |\ ] : v(\downarrow) \multimap t(\downarrow)$

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$$\lambda P.[x_1 | named(x_1, Peter)] \; ; \; P(x_1) : (e_1 \multimap t_2) \multimap t_2$$

$$\lambda x.\lambda F, [e_1 | arrive(e_1), nsubj(e_1, x)] \; ; F(e_1) : e_1 \multimap (v_2 \multimap t_2) \multimap t_2$$

$$\lambda\_.[\ |\ ] : v_2 \multimap t_2$$

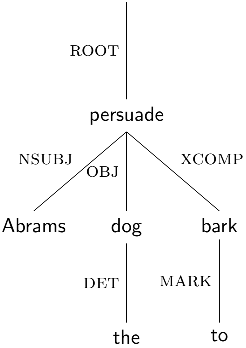
Interpretation in Glue

$$\dfrac{\dfrac{[\![Peter]\!] : (e_1 \multimap t_2) \multimap t_2 \qquad \dfrac{\dfrac{\dfrac{[\![arrived]\!] : e_1 \multimap (v_2 \multimap t_2) \multimap t_2 \quad [y : e_1]^1}{[\![arrived]\!](y) : (v_2 \multimap t_2) \multimap t_2} \multimap_E \quad [\![\mathtt{root}]\!] : v_2 \multimap t_2}{[\![arrived]\!](y)([\![\mathtt{root}]\!]) : t_2} \multimap_E}{\lambda y.[\![arrived]\!](y)([\![\mathtt{root}]\!]) : e_1 \multimap t_2} \multimap_{I,1}}{[\![Peter]\!](\lambda y.[\![arrived]\!](y)([\![\mathtt{root}]\!])) : t_2}} \multimap_E$$

$$\left(\lambda P.\boxed{\begin{array}{l} x_1 \\ \hline named(x_1, Peter) \end{array}}; P(x_1)\right)\left(\lambda y.\left(\lambda x.\lambda F.\boxed{\begin{array}{l} e_1 \\ \hline arrive(e_1) \\ nsubj(e_1, x) \end{array}}; F(e_1)\right)(y)\left(\lambda V_{-}.\boxed{\begin{array}{l} \ \\ \hline \ \end{array}}\right)\right)$$

$$\rightsquigarrow_\beta \boxed{\begin{array}{l} x_1 \ \ e_1 \\ \hline named(x_1, Peter) \\ arrive(e_1) \\ nsubj(e_1, x_1) \end{array}}$$

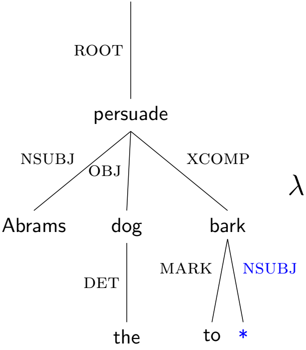
Control



$$\lambda P.\lambda y.\lambda x.\lambda F. \begin{array}{|l|}\hline e_1 \;\; x_1 \;\; x_2 \\ \hline persuade(e_1) \\ controldep(e_1, x_2) \\ xcomp(e_1, x_1) \\ obj(e_1, y) \\ nsubj(e_1, x) \\ q : P(x_2)(\lambda\_.[\ |\ ]) \\ \hline \end{array} \; ; F(e_1)$$

$$(e_{\downarrow \text{XCOMP NSUBJ}} \multimap (v_{\downarrow \text{XCOMP}} \multimap t_{\downarrow \text{XCOMP}}) \multimap t_{\downarrow \text{XCOMP}}) \multimap (e_{\downarrow \text{NSUBJ}}) \multimap (e_{\downarrow \text{OBJ}}) \multimap (v_{\downarrow} \multimap t_{\downarrow}) \multimap t_{\downarrow}$$

Control



$$\lambda P.\lambda y.\lambda x.\lambda F. \begin{array}{|l|}\hline e_1 \ x_1 \ x_2 \\ \hline persuade(e_1) \\ controldep(e_1, x_2) \\ xcomp(e_1, x_1) \\ obj(e_1, y) \\ nsubj(e_1, x) \\ q : P(x_2)(\lambda\_.[\ |\ ]) \\ \hline \end{array} \ ; F(e_1)$$

$$(e_8 \multimap (v_6 \multimap t_6) \multimap t_6) \multimap e_4 \multimap e_1 \multimap (v_2 \multimap t_2) \multimap t_2$$

$$\dfrac{\llbracket persuade \rrbracket : ((v_6 \multimap t_6) \multimap t_6) \multimap e_4 \multimap e_1 \multimap (v_2 \multimap t_2) \multimap t_2 \qquad \llbracket bark \rrbracket : (v_6 \multimap t_6) \multimap t_6}{\llbracket persuade \rrbracket(\llbracket bark \rrbracket) : e_4 \multimap e_1 \multimap (v_2 \multimap t_2) \multimap t_2}$$

$$\dfrac{\llbracket persuade \rrbracket(\llbracket bark \rrbracket) : e_4 \multimap e_1 \multimap (v_2 \multimap t_2) \multimap t_2 \qquad [u : e_4]^1}{\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u) : e_1 \multimap (v_2 \multimap t_2) \multimap t_2}$$

$$\dfrac{\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u) : e_1 \multimap (v_2 \multimap t_2) \multimap t_2 \qquad [v : e_1]^2}{\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v) : (v_2 \multimap t_2) \multimap t_2}$$

$$\dfrac{\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v) : (v_2 \multimap t_2) \multimap t_2 \qquad \llbracket \mathtt{root} \rrbracket : v_2 \multimap t_2}{\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket) : t_2}$$

$$\dfrac{\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket) : t_2}{\lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket) : e_4 \multimap t_2}\ 1$$

$$\dfrac{\vdots \atop \llbracket the \rrbracket(\llbracket dog \rrbracket) : (e_4 \multimap t_2) \multimap t_2 \qquad \lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket) : e_4 \multimap t_2}{\llbracket the \rrbracket(\llbracket dog \rrbracket)(\lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket)) : t_2}$$

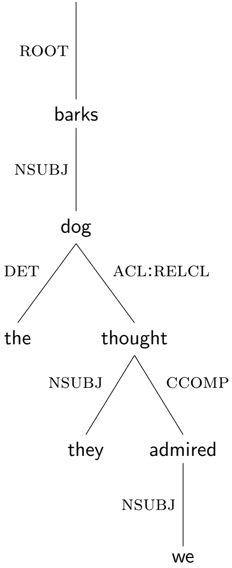
$$\dfrac{\llbracket the \rrbracket(\llbracket dog \rrbracket)(\lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket)) : t_2}{\lambda v.\llbracket the \rrbracket(\llbracket dog \rrbracket)(\lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket)) : e_1 \multimap t_2}\ 2$$

$$\dfrac{\llbracket Abrams \rrbracket : (e_1 \multimap t_2) \multimap t_2 \qquad \lambda v.\llbracket the \rrbracket(\llbracket dog \rrbracket)(\lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket)) : e_1 \multimap t_2}{\llbracket Abrams \rrbracket(\lambda v.\llbracket the \rrbracket(\llbracket dog \rrbracket)(\lambda u.\llbracket persuade \rrbracket(\llbracket bark \rrbracket)(u)(v)(\llbracket \mathtt{root} \rrbracket))) : t_2}$$

$\rightsquigarrow_\beta$

$x_1 \; x_2 \; x_3 \; e_1 \; p_1$
$named(x_1, abrams), ant(x_2)$ $\partial(dog(x_2)), persuade(e_1)$ $nsubj(e_1, x_1), obj(e_1, x_2)$ $controldep(e_1, x_3), xcomp(e_1, p_1)$ $p_1 :$ [e_2 | $bark(e_2)$, $nsubj(e_2, x_3)$]

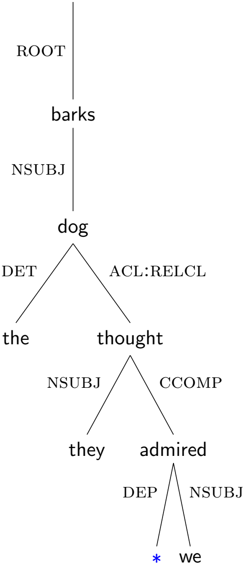
Relative clauses



$$\lambda P.\lambda V.\lambda x.P(x); V(x)(\lambda\_.[\ |\ ])$$

$$(e_{\uparrow} \multimap t_{\uparrow}) \multimap$$
$$(e_{\downarrow dep^{*}\, dep\{PType=Rel\}} \multimap (v_{\downarrow} \multimap t_{\downarrow}) \multimap t_{\downarrow}) \multimap$$
$$e_{\uparrow} \multimap t_{\uparrow}$$

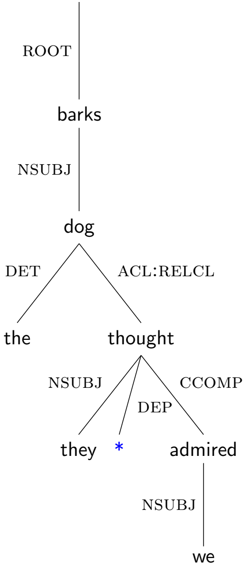
Relative clauses



$$\lambda P.\lambda V.\lambda x.P(x); V(x)(\lambda\_.[\ |\ ])$$

$$(e_2 \multimap t_2) \multimap$$
$$(e_9 \multimap (v_4 \multimap t_4) \multimap t_4) \multimap$$
$$e_2 \multimap t_2$$

Relative clauses



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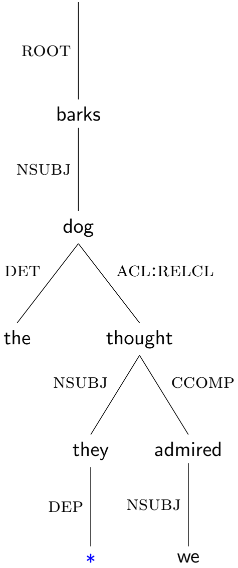
$$e_2 \multimap t_2$$

Relative clauses



$$\lambda P.\lambda V.\lambda x.P(x); V(x)(\lambda\_.[\ |\ ])$$

$$(e_2 \multimap t_2) \multimap$$
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$$e_2 \multimap t_2$$

Other rules

relation = case; $\uparrow\uparrow$ {coarsePos = VERB} $\rightarrow$

lam(Y,(lam(X,drs([ ],[rel(:LEMMA:,Y,X)])))) : e($\uparrow$)$\multimap$v($\uparrow\uparrow$)$\multimap$t($\downarrow$)

relation = case; $\uparrow\uparrow$ {coarsePos = VERB} $\rightarrow$

relation = case $\rightarrow$

lam(Y,(lam(X,drs([ ],[rel(:LEMMA:,Y,X)])))) : e($\uparrow$)$\multimap$e($\uparrow\uparrow$)$\multimap$t($\downarrow$)

coarsePos = DET, lemma = a; $\uparrow$ cop { } $\rightarrow$

relation = conj; det { } $\rightarrow$

lam(X,lam(Q,lam(C,lam(Y,app(app(C,drs([],[leq(X,Y)])),app(app(Q,C),Y)))))

e($\downarrow$)$\multimap$((t($\uparrow$)$\multimap$t($\uparrow$)$\multimap$t($\uparrow$))$\multimap$n($\uparrow$))$\multimap$(t($\uparrow$)$\multimap$t($\uparrow$)$\multimap$t($\uparrow$))$\multimap$n($\uparrow$)

Plan

Discussion of output

x_1 e_1
$named(x_1, Peter)$ $arrive(e_1)$ $nsubj(e_1, x_1)$

- What kind of θ-role is 'nsubj'?
  - A syntactic name, lifted from the arc label.
  - In and of itself, uninformative.

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- Lexical knowledge in the form of meaning postulates such as (5) can be harnessed to further specify the meaning representation.

(5) $\forall e \forall x((arrive(e) \wedge nsubj(e, x)) \rightarrow theme(e, x))$

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$x_1\ x_2\ x_3\ e_1\ p_1$
$\ldots$ $persuade(e_1), obj(e_1, x_2), controldep(e_1, x_3), xcomp(e_1, p_1)$ p_1 : [e_2 | $\ldots, nsubj(e_2, x_3)$]

- The *persuade* + `xcomp` meaning constructor has
  - introduced an *xcomp* relation between the persuading event e_1 and the proposition p_1 that there is a barking event e_2, and
  - introduced an individual x_3 as the *nsubj* of e_2 and the *controldep* of e_1.

$x_1 \ x_2 \ x_3 \ e_1 \ p_1$
$\ldots$ $persuade(e_1), obj(e_1, x_2), controldep(e_1, x_3), xcomp(e_1, p_1)$ $p_1 : \boxed{e_2 \mid \ldots, nsubj(e_2, x_3)}$

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- But the information that *persuade* is an object control verb can again be encoded in a meaning postulate:

$$\forall e \forall x ((persuade(e) \wedge controldep(e, x)) \rightarrow obj(e, x))$$

$x_1\ x_2\ x_3\ e_1\ p_1$
...
$persuade(e_1), obj(e_1, x_2), obj(e_1, x_3), xcomp(e_1, p_1)$
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$persuade(e_1), obj(e_1, x_2), obj(e_1, x_3), xcomp(e_1, p_1)$
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  $$\forall e \forall x((persuade(e) \wedge controldep(e, x)) \rightarrow obj(e, x))$$

- With thematic uniqueness, we get $x_2 = x_3$ in this case.
- Blurs the distinction between lexical syntax and semantics.

VP/Sentence coordination: He hemmed and hawed

$x_1 \; e_2 \; e_3$
$pron.he(x_1)$ $hem(e_2)$ $nsubj(e_2, x_1)$ $haw(e_3)$

- No way to distinguish V/VP/S coordination in DG because of the overt token constraint
- No argument sharing because of the unique head constraint

NP Coordination: Abrams and/or Browne danced

$e_1 \; x_2 \; x_3 \; x_4$

$dance(e_1)$
$nsubj(e, x_2)$
$named(x_3, browne)$
$named(x_4, abrams)$
$x_3 \sqsubseteq x_2$
$x_4 \sqsubseteq x_2$

$e_1 \; x_2 \; x_3 \; x_4$

$dance(e_1)$
$nsubj(e, x_2)$
$named(x_3, browne)$
$named(x_4, abrams)$
$[\; x_3 \sqsubseteq x_2 \;] \vee [\; x_4 \sqsubseteq x_2 \;]$

Argument/adjunct distinction

$e_1\ x_2\ x_3$	$e_1\ x_2\ x_3$
$rely(e_1)$ $named(x_2, kim)$ $named(x_3, sandy)$ $on(x_3, e_1)$	$leave(e_1)$ $named(x_2, kim)$ $named(x_3, tuesday)$ $on(x_3, e_1)$

- Again, we will have to rely on meaning postulates to resolve the *on* relation to a thematic role in one case and a temporal relation in the other

Evaluation

- What we have so far is a proof of concept tested on carefully crafted examples
  - application of LFG techniques (functional uncertainties) to enrich underspecified UD syntax
  - application of glue semantics to dependency structures

Evaluation

- What we have so far is a proof of concept tested on carefully crafted examples
  - application of LFG techniques (functional uncertainties) to enrich underspecified UD syntax
  - application of glue semantics to dependency structures
- Very far from something practically useful
  - Basic coverage of UD relations except `vocative`, `dislocated`, `clf`, `list`, `parataxis`, `orphan`
  - Little or no work on interactions, special constructions, real data noise

Pros and cons of glue semantics

- No need for binarization
- Flexible approach to scoping yield different readings
- Hard to restrict unwanted/non-existing scopings
- Computing lots of uninteresting scope differences

Unwanted scopings

$$\lambda F. \begin{array}{|l|}\hline e \\ \hline arrive(e) \\ \hline \end{array} ; F(e) : (v_1 \multimap t_1) \multimap t_1$$

$$\lambda\_. \begin{array}{|l|}\hline \\ \hline \\ \hline \end{array} : v_1 \multimap t_1$$

It is clear which DRS sentence-level operators (negation, auxiliaries etc.) should target!

- Modalities in the linear logic
- Different types for the two DRSs

Efficient scoping

- Two parameters:
  - level of scope
  - order of combination of quantifiers at each level
- We currently naively compute everything with a light-weight prover $\rightarrow$ obvious performance problems
- Disallow intermediate scopings?
- Structure sharing across derivations (building on work in an LFG context)

Conclusions

- Theoretical achievement: application of glue to dependency grammar

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Conclusions

- Theoretical achievement: application of glue to dependency grammar
- Practical achievement: an interesting proof of concept
- But lots of work remains
  - Support for partial proofs
  - Axiomatization of lexical knowledge
  - Ambiguity management

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