From Tree Adjoining Grammars to Higher Order Representations of Abstract Meaning Representations via Abstract Categorial Grammars

Rasmus Blanck, Aleksandre Maskharashvili
Centre for Linguistic Theory and Studies in Probability,
University of Göteborg

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- Based on frames
- Uniquely rooted directed acyclic graph (DAG) with labeled edges and nodes
  - graph nodes encode entities and events (neo-Davidsonian)
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A boy wants to go / All boys want to / The boy wants to go / ...
- all have same AMR semantics:

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  - drawback: coreference is lost

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Operations on trees –

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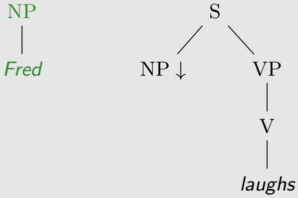

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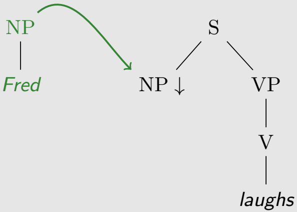

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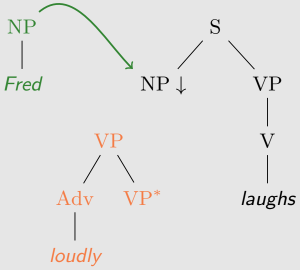

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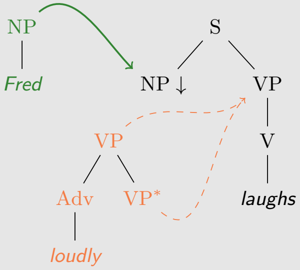

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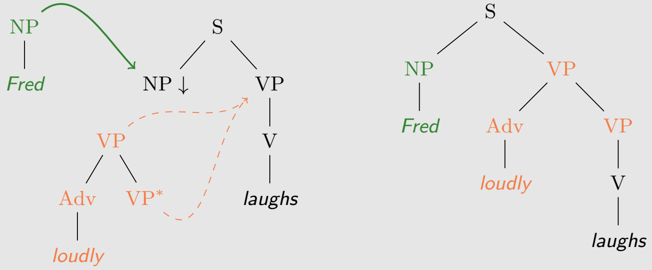

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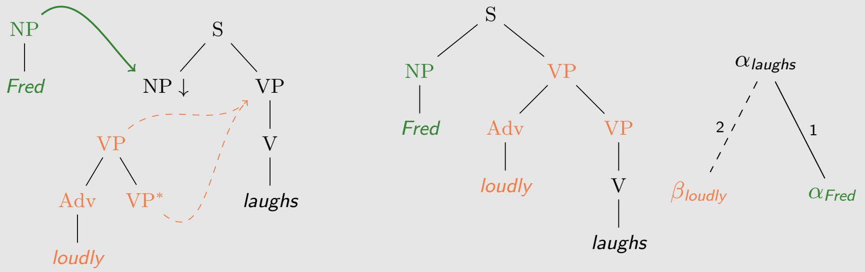

1 **ACG**

- ACG definition

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Parsing 2nd order ACGs are **reversible** (Salvati, 2005; Kanazawa, 2007)

ACG definition

Definition (ACG)

An abstract categorial grammar (ACG) $\mathscr{G}$ is a quadruple $\langle \Sigma_1, \Sigma_2, \mathscr{L}, s \rangle$, where

1. Σ_1 and Σ_2 are higher-order linear signatures, called the *abstract* vocabulary and the *object* vocabulary, respectively;
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Modularity: ACGs can be composed as lexicons are functions.

TAG as ACGs

TAG derivation trees $\Lambda(\Sigma_{TAG})$

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Derived trees $\Lambda(\Sigma_{trees})$

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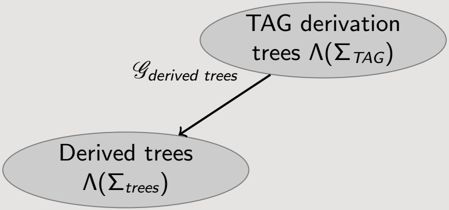

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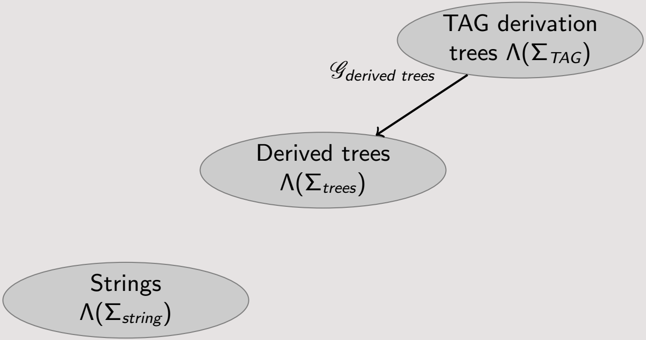
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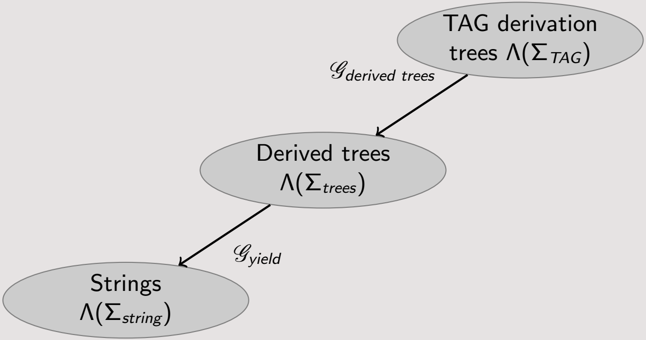

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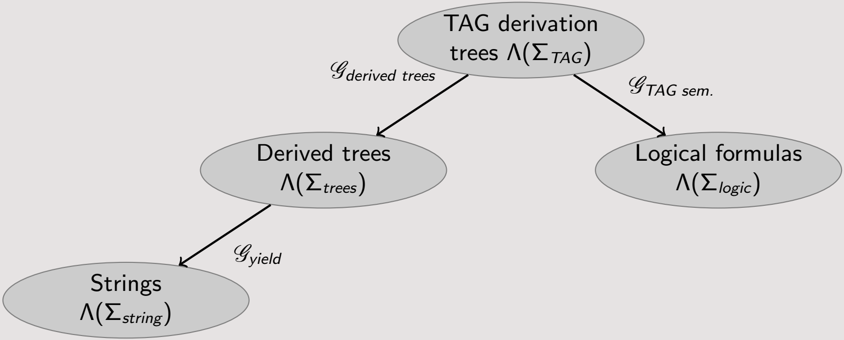
TAG as ACGs + Montague semantics (Pogodalla, 2004a)



From TAG derivation to TAG derived trees

Derivation trees

Their interpretations as derived trees

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C_{Fred} : **NP**

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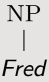

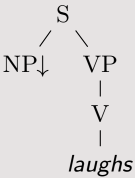

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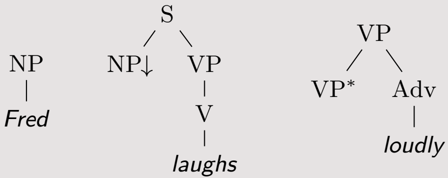

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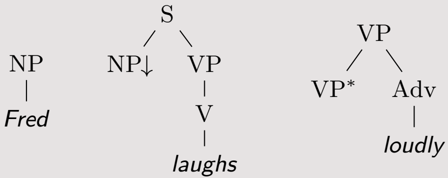

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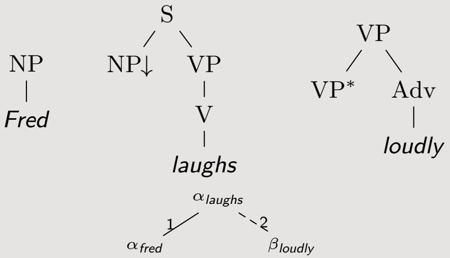

$$M_0 = C_{left}\ \mathsf{I}_\mathsf{S}\ (C_{loudly}\ \mathsf{I}_\mathsf{V})\ C_{Fred}$$

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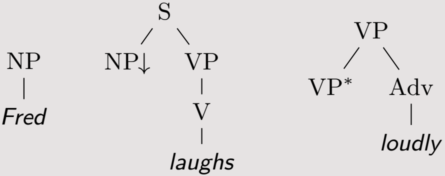

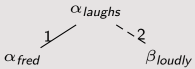

$$M_0 = C_{left}\ \mathsf{I}_{\mathbf{S}}\ (C_{loudly}\ \mathsf{I}_{\mathbf{V}})\ C_{Fred}$$

$$\mathscr{G}_{yield} \circ \mathscr{G}_{derived\ trees}(M_0) = \textit{Fred} + \textit{loudly} + \textit{laughs}$$

From TAG derivation to Montague Translations (Pogodalla, 2004b)

Derivation trees

Interpretations into Montague Grammar

From TAG derivation to Montague Translations (Pogodalla, 2004b)

Derivation trees

C_{Fred} : **NP**

Interpretations into Montague Grammar

$\lambda P.\, P\, \texttt{fred}$

$$\begin{array}{c}\mathrm{NP}\\ |\\ \textit{Fred}\end{array}$$

From TAG derivation to Montague Translations (Pogodalla, 2004b)

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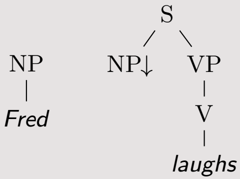


From TAG derivation to Montague Translations (Pogodalla, 2004b)

Derivation trees

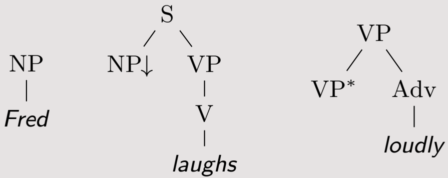
C_{Fred} : $\mathbf{NP}$

C_{laughs} : $\mathbf{S}_{\mathsf{A}} \multimap \mathbf{VP}_{\mathsf{A}} \multimap \mathbf{NP} \multimap \mathbf{S}$

Interpretations into Montague Grammar

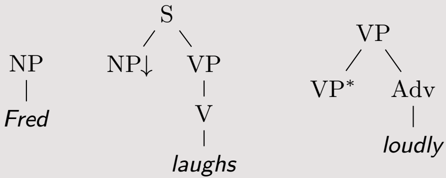
$\lambda P.\, P\, \texttt{fred}$

$\lambda\, \mathbf{a^S}\, \mathbf{a^V}\, \mathbf{np}.\, \mathbf{a^S}\, (\mathbf{np}\, (\mathbf{a^V}\, (\lambda x.\, \texttt{smile}\, x)))$



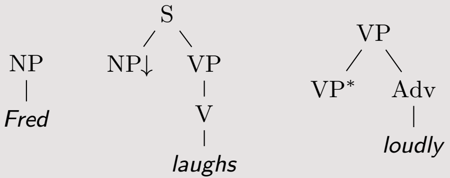
From TAG derivation to Montague Translations (Pogodalla, 2004b)

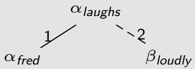
Derivation trees	Interpretations into Montague Grammar
$C_{Fred} : \mathbf{NP}$	$\lambda P.\, P\, \texttt{fred}$
$C_{laughs} : \mathbf{S}_{\mathrm{A}} \multimap \mathbf{VP}_{\mathrm{A}} \multimap \mathbf{NP} \multimap \mathbf{S}$	$\lambda\, \mathbf{a^S}\, \mathbf{a^V}\, \mathbf{np}.\, \mathbf{a^S}\, (\mathbf{np}\, (\mathbf{a^V}\, (\lambda x.\, \texttt{smile}\, x)))$
$C_{loudly} : \mathbf{VP}_{\mathrm{A}} \multimap \mathbf{VP}_{\mathrm{A}}$	$\lambda\, \mathbf{a^V}.\, \mathbf{a^V}\, (\lambda x.\, \texttt{loud}\, x))$



From TAG derivation to Montague Translations (Pogodalla, 2004b)

Derivation trees	Interpretations into Montague Grammar
C_{Fred} : $\mathbf{NP}$	$\lambda P.\, P\ \mathtt{fred}$
C_{laughs} : $\mathbf{S}_{\mathrm{A}} \multimap \mathbf{VP}_{\mathrm{A}} \multimap \mathbf{NP} \multimap \mathbf{S}$	$\lambda\, \mathbf{a}^{\mathbf{S}}\, \mathbf{a}^{\mathbf{V}}\, \mathbf{np}.\, \mathbf{a}^{\mathbf{S}}\, (\mathbf{np}\, (\mathbf{a}^{\mathbf{V}}\, (\lambda x.\, \mathtt{smile}\, x)))$
C_{loudly} : $\mathbf{VP}_{\mathrm{A}} \multimap \mathbf{VP}_{\mathrm{A}}$	$\lambda\, \mathbf{a}^{\mathbf{V}}.\, \mathbf{a}^{\mathbf{V}}\, (\lambda x.\, \mathtt{loud}\, x))$
$\mathrm{I}_{\mathbf{X}_{\mathbf{A}}}$: $\mathbf{X}_{\mathbf{A}}$	$\lambda x.x$

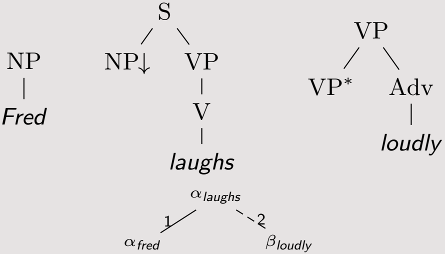




$$M_0 = C_{laughs}\ \mathrm{I}_{\mathbf{S}}\ (C_{loudly}\ \mathrm{I}_{\mathbf{V}})\ C_{Fred}$$

From TAG derivation to Montague Translations (Pogodalla, 2004b)

Derivation trees	Interpretations into Montague Grammar
C_{Fred} : $\mathbf{NP}$	$\lambda P.\, P\, \mathtt{fred}$
C_{laughs} : $\mathbf{S}_{\mathrm{A}} \multimap \mathbf{VP}_{\mathrm{A}} \multimap \mathbf{NP} \multimap \mathbf{S}$	$\lambda\, \mathbf{a^S}\, \mathbf{a^V}\, \mathbf{np}.\, \mathbf{a^S}\, (\mathbf{np}\, (\mathbf{a^V}\, (\lambda x.\, \mathtt{smile}\, x)))$
C_{loudly} : $\mathbf{VP}_{\mathrm{A}} \multimap \mathbf{VP}_{\mathrm{A}}$	$\lambda\, \mathbf{a^V}.\, \mathbf{a^V}\, (\lambda x.\, \mathtt{loud}\, x))$
$\mathrm{I}_{\mathbf{X_A}}$: $\mathbf{X_A}$	$\lambda x.x$



$$M_0 = C_{laughs}\ \mathrm{I}_{\mathbf{S}}\ (C_{loudly}\ \mathrm{I}_{\mathbf{V}})\ C_{Fred}$$

$$\mathscr{L}_{Log}(M_0) = \mathtt{loud}\,(\mathtt{smile\ fred})$$

TAG derivation trees to HOL (Pogodalla, 2017)

Constants of Σ_{TAG}	Their interpretations by $\mathscr{G}_{TAG\ sem.}$
$C_{fred} : \mathbf{NP}$	$\lambda P. P\,\mathtt{fred} : (e \to t) \to t$
$C_{woman} : \mathbf{n_A} \multimap \mathbf{NP}$	$\lambda D.\lambda q\,.D\,\mathtt{woman}\,q$
$C_{smart} : \mathbf{n_A} \multimap \mathbf{n_A}$	$\lambda D.\ \lambda n\,.\lambda q\,.\,D\,(\lambda\,x.\,(\mathtt{smart}\ x) \land (n\ x))q$
$C_{every}, C_{each} : \mathbf{n_A}$	$\lambda\,P\,Q\,.\forall\,x.\,(P\,x)\ \supset\ (Q\,x)$
$C_{some},\ C_a : \mathbf{n_A}$	$\lambda\,P\,Q\,.\exists\,x.\,(P\,x)\ \land\ (Q\,x)$
$C_{kissed} : \mathbf{S}_A \multimap \mathbf{VP}_A \multimap \mathbf{NP} \multimap \mathbf{NP} \multimap \mathbf{S}$	$\lambda adv_s\ adv_v\ sbj\ obj.\ adv_s\,(sbj\,(\lambda x.(obj\,(adv_v(\lambda y.\mathtt{kiss}\,x\,y)))))$
$\mathsf{I}_X : X_A$	$\lambda x.x$
$\mathbf{S}$	t

Continuations, event semantics, ACG

Previous approaches

- syntax-event semantics interface using ACG (Winter and Zwarts, 2011) – their grammar is not TAG;
- syntax-event semantic interface (Champollion, 2015):

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  - uses continuations: verbs are of type $(v \to t) \to t$
  - negation scopes over existentially closed formula $(\neg\exists w \ldots)$
  - no distinction of arguments and adjuncts, e.g.

$$\lambda x.go\ x \text{ VS } \lambda f.\exists w.go(w) \wedge f(w)$$

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- syntax-event semantics interface using ACG (Winter and Zwarts, 2011) – their grammar is not TAG;
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$$\lambda x.go\ x \text{ VS } \lambda f.\exists w.go(w) \wedge f(w)$$

Our approach

- use continuations, like (Champollion, 2015)
- negation scopes over event quantifier, like (Champollion, 2015)
- retain arguments within a lexical entry of a verb, like AMR
- (universal) quantification, like (Stabler, 2018)

Interpretation as HOL formulas modeling event semantics: First try

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- everything should get a chance for a continuation
- but one has to know when to stop (close)

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$$
\begin{array}{ll}
\mathbf{S} & := (v \to t) \to t \\
\mathbf{T} & := t \\
\mathit{Closure} & := \lambda P.P\ \mathit{True}\ :\ ((v \to t) \to t) \to t \\
C_{john} & := \lambda P.\ P\,\mathrm{john} \\
C_{walks} & := \lambda adv_s\ adv_v\ subj.\ adv_s\,(subj\,(adv_v(\lambda x.\lambda h.\exists w.\,(\mathrm{walk}\,w) \wedge (arg_0\,w\,x) \wedge (h\,w))) \\
C_{smart} & := \lambda D.\lambda n.\lambda q.\lambda f.D(\lambda xh.(n\,x\,h) \wedge (\mathrm{smart}\,x))q\,f \\
C^{\mathbf{n_A}}_{every} & := \lambda p.\lambda q.\lambda f.\forall x.(p\,x\,f) \supset (q\,x\,f) \\
C^{\mathbf{n_A} \multimap \mathbf{NP}}_{woman} & := \lambda D.D(\lambda\,x\,h.(\mathrm{woman}\,x \wedge h\,x)) \\
C^{\mathbf{S}_A \multimap \mathbf{S}_A}_{certainly} & := \lambda m.\,\lambda V.\ m\,(\lambda h.V(\lambda v.(\mathrm{certainly}\,v) \wedge (h\,v)) \\
C^{\mathbf{VP}_A \multimap \mathbf{VP}_A}_{fast} & := \lambda m.\,\lambda V.\,m\,(\lambda x.\lambda h.Vx(\lambda v.(\mathrm{fast}\,v) \wedge (h\,v))) \\
C^{\mathbf{VP}_A}_{does\ not} & := \lambda Vxh.\neg(V\,x\,h)
\end{array}
$$

First try: Results

(1) Every smart woman walks.

$M_1 = \mathit{Closure}\,(C_{walks}\,\mathsf{I_S}\,\mathsf{I_{VP}}\,(C_{woman}\,(C_{smart}\;C_{every})))\;\;:\mathbf{T}$

$$M_1 := \quad \forall x(\text{woman}\,x \wedge \text{smart}\,x \supset \exists w\,(\text{walk}\,w) \wedge (\mathit{arg}_0\,w\,x)) \qquad \checkmark$$

First try: Results

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$M_1 = \mathit{Closure}\,(C_{walks}\; \mathsf{I}_{\mathbf{S}}\; \mathsf{I}_{\mathbf{VP}}\; (C_{woman}\; (C_{smart}\; C_{every})))\;\; : \mathbf{T}$

(2) John does not walk.
$M_2 = \mathit{Closure}\,(C_{walks}\; \mathsf{I}_{\mathbf{S}}\;\; C_{does\ not}\;\; C_{john})\;\; : \mathbf{T}$

$M_1 := \quad \forall x(\text{woman}\, x \wedge \text{smart}\, x \supset \exists w\, (\text{walk}\, w) \wedge (arg_0\; w\; x))$ ✓

$M_2 := \quad \neg\exists w\, (\text{walk}\, w) \wedge (arg_0\; w\; \text{john})$ ✓

First try: Results

(1) Every smart woman walks.
$M_1 = \mathit{Closure}\,(C_{walks}\ \mathsf{I_S}\ \mathsf{I_{VP}}\ (C_{woman}\ (C_{smart}\ C_{every})))\ \ : \mathbf{T}$

(2) John does not walk.
$M_2 = \mathit{Closure}\,(C_{walks}\ \mathsf{I_S}\ \ C_{does\ not}\ \ C_{john})\ \ : \mathbf{T}$

(3) Every smart woman walks fast.
$M_3 = \mathit{Closure}\,(C_{walks}\mathsf{I_S}(C_{fast}\ \mathsf{I_{VP}})(C_{woman}\ (C_{smart}\ C_{every})))\ \ : \mathbf{T}$

$M_1 := \quad \forall x(\text{woman}\, x \wedge \text{smart}\, x \supset \exists w\, (\text{walk}\, w) \wedge (\mathit{arg}_0\, w\, x))$ ✓
$M_2 := \quad \neg\exists w\, (\text{walk}\, w) \wedge (\mathit{arg}_0\, w\, \text{john})$ ✓
$M_3 := \quad \forall x(\text{woman}\, x \wedge \text{smart}\, x \wedge \text{fast}\, x \supset \exists w(\text{walk}\, w) \wedge (\mathit{arg}_0\, w\, x) \wedge (\text{fast}\, w))$

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(2) John does not walk.
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(3) Every smart woman walks fast.
$M_3 = \mathit{Closure}\,(C_{walks}\mathsf{I}_{\mathbf{S}}(C_{fast}\ \mathsf{I}_{\mathbf{VP}})(C_{woman}\ (C_{smart}\ C_{every})))\ \ : \mathbf{T}$

(4) Certainly, every smart woman walks.
$M_4 = \mathit{Closure}\,(C_{walks}(C_{certainly}\ \mathsf{I}_{\mathbf{S}})\mathsf{I}_{\mathbf{VP}}(C_{woman}\ (C_{smart}\ C_{every})))\ \ : \mathbf{T}$

$M_1 := \quad \forall x(\text{woman}\,x \wedge \text{smart}\,x \supset \exists w\,(\text{walk}\,w) \wedge (\mathit{arg}_0\ w\,x)) \qquad \checkmark$

$M_2 := \quad \neg\exists w\,(\text{walk}\,w) \wedge (\mathit{arg}_0\ w\,\text{john}) \qquad \checkmark$

$M_3 := \quad \forall x(\text{woman}\,x \wedge \text{smart}\,x \wedge \text{fast}\,x \supset \exists w(\text{walk}\,w) \wedge (\mathit{arg}_0\ w\,x) \wedge (\text{fast}\,w))$

$M_4 := \quad \forall x\,(\text{woman}\,x \wedge \text{smart}\,x \wedge \text{certainly}\,x \supset \exists w(\text{walk}\,w) \wedge (\mathit{arg}_0\ w\,x) \wedge (\text{certainly}\,w))$

Locating the problem

$$
\begin{array}{ll}
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C_{smart} & := \lambda D.\lambda n.\lambda q.\lambda f.D(\lambda xh.(n\,x\,h) \wedge (\mathrm{smart}\,x))q\,f \\
C_{every}^{\mathbf{n_A}} & := \lambda p.\lambda q.\lambda f.\forall x.(p\,x\,f) \supset (q\,x\,f) \\
C_{woman}^{\mathbf{n_A} \multimap \mathbf{NP}} & := \lambda D.D(\lambda\,x\,h.(\mathrm{woman}\,x \wedge h\,x)) \\
C_{certainly}^{\mathbf{S}_A \multimap \mathbf{S}_A} & := \lambda m.\,\lambda V.\ m\,(\lambda h.V(\lambda v.(\mathrm{certainly}\,v) \wedge (h\,v)) \\
C_{fast}^{\mathbf{VP}_A \multimap \mathbf{VP}_A} & := \lambda m.\,\lambda V.\,m\,(\lambda x.\lambda h.\,Vx(\lambda v.(\mathrm{fast}\,v) \wedge (h\,v))) \\
C_{does\ not}^{\mathbf{VP}_A} & := \lambda Vxh.\neg(V\,x\,h)
\end{array}
$$

Second try: No continuations for noun phrases

New interpretations

$$
\begin{aligned}
C_{john} &:= \lambda P.\, P\,\mathrm{john} : (e \to \Omega) \to \Omega \\
C_{walks} &:= \lambda adv_s\; adv_v\; subj\,.adv_s\,(subj\,(adv_v(\lambda x.\lambda h.\exists w.\,(\mathrm{walk}\; w) \wedge (arg_0\; w\; x) \wedge (h\, w)))) \\
C_{woman} &:= \lambda D.D(\lambda\, x.\mathrm{woman}\, x) \\
C_{every} &:= \lambda PQ.\lambda h.\forall x(Px \supset Qxh) : (e \to t) \to (e \to \Omega) \to \Omega \\
C_{a} &:= \lambda PQ.\lambda h.\exists x(Px \wedge Qxh) : (e \to t) \to (e \to \Omega) \to \Omega \\
C_{smart} &:= \lambda D.\lambda n.\lambda q.\lambda f\,.D(\lambda x.(n\, x\,) \wedge (\mathrm{smart}\; x))q\, f \\
C_{certainly} &:= \lambda m.\, \lambda V.\;\; m\,(\lambda h.V(\lambda v.(\mathrm{certainly}\; v) \wedge (h\, v)) \\
C_{fast} &:= \lambda m.\, \lambda V\,.\, m\,(\lambda x.\lambda h.\,Vx(\lambda v.(\mathrm{fast}\; v) \wedge (h\, v))) \\
C_{does\ not} &:= \lambda Vxh.\neg(V\; x\; h) \\
C_{itisnotthecase} &:= \lambda S\; h.\neg(S\; h)
\end{aligned}
$$

Where: $\Omega \equiv_{\mathrm{def}} (v \to t) \to t$

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\begin{array}{ll}
C_{john} & := \lambda P.\, P\, \text{john} : (e \to \Omega) \to \Omega \\
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C_{woman} & := \lambda D.D(\lambda\, x.\text{woman}\, x) \\
C_{every} & := \lambda PQ.\lambda h.\forall x(Px \supset Qxh) : (e \to t) \to (e \to \Omega) \to \Omega \\
C_{a} & := \lambda PQ.\lambda h.\exists x(Px \wedge Qxh) : (e \to t) \to (e \to \Omega) \to \Omega \\
C_{smart} & := \lambda D.\lambda n.\lambda q.\lambda f.D(\lambda x.(n\, x) \wedge (\text{smart}\, x))q\, f \\
C_{certainly} & := \lambda m.\, \lambda V.\ m\, (\lambda h.V(\lambda v.(\text{certainly}\, v) \wedge (h\, v)) \\
C_{fast} & := \lambda m.\, \lambda V.\, m\, (\lambda x.\lambda h.Vx(\lambda v.(\text{fast}\, v) \wedge (h\, v))) \\
C_{does\ not} & := \lambda Vxh.\neg(V\, x\, h) \\
C_{itisnotthecase} & := \lambda S\, h.\neg(S\, h)
\end{array}
$$

Where: $\Omega \equiv_{\text{def}} (v \to t) \to t$

$$M_3 := \forall x(\text{woman}\, x \wedge \text{smart}\, x \supset \exists w(\text{walk}\, w) \wedge (arg_0\, w\, x) \wedge (\text{fast}\, w))$$

$$M_4 := \forall x(\text{woman}\, x \wedge \text{smart}\, x \supset \exists w(\text{walk}\, w) \wedge (arg_0\, w\, x) \wedge (\text{certainly}\, w))$$

Bonus: Coreference, Raising

$$
\begin{array}{lll}
C_{wants}: & \mathbf{S}_A \multimap \mathbf{VP}_A \multimap \mathbf{NP} \multimap \mathbf{S}'_A & C_{to\text{-}sleep}: \quad \mathbf{S}'_A \multimap \mathbf{S} \\
\hline
C_{wants} := & \lambda adv_s\, adv_v\, subj.\lambda Pred.adv_s\,(subj(adv_v.\lambda x\, h. & \\
 & \exists w((\mathrm{want}\, w) \wedge (h\, w) \wedge (arg_0\, w\, x) \wedge Pred(\lambda Q.Q\, x)(\lambda r.\, Arg_1\, w\, r)) & \\
C_{to\text{-}sleep} := & \lambda cont.cont(\lambda subj.subj(\lambda x.\lambda f.\exists u.(\mathrm{sleep}\, u) \wedge (arg_0\, u\, x) \wedge (f\, u)) & \\
\mathbf{S}'_A := & (((e \to \Omega) \to \Omega) \to \Omega) \to \Omega &
\end{array}
$$

(5) a. John wants to sleep.

$M_5 = Closure(C_{to\text{-}sleep}\,(C_{wants}\,\mathrm{I}_{\mathbf{S}}\,\mathrm{I}_{\mathbf{VP}}\,C_{john}))\ :\ \mathbf{T}$

$\exists w(\mathrm{want}\, w) \wedge (arg_0\, w\, \mathrm{john}) \wedge (\exists u(\mathrm{sleep}\, u) \wedge (Arg_1\, w\, u) \wedge (arg_0\, u\, \mathrm{john}))$

b. Every boy wants to sleep.

$M_6 = Closure(C_{to\text{-}sleep}\,(C_{wants}\,\mathrm{I}_{\mathbf{S}}\,\mathrm{I}_{\mathbf{VP}}(C_{boy}\,C_{every})))\ :\ \mathbf{T}$

$\forall x(\mathrm{boy}\, x \supset \exists w(\mathrm{want}\, w) \wedge (arg_0\, w\, x) \wedge (\exists u.(\mathrm{sleep}\, u) \wedge (Arg_1\, w\, u) \wedge (arg_0\, u\, x)))$

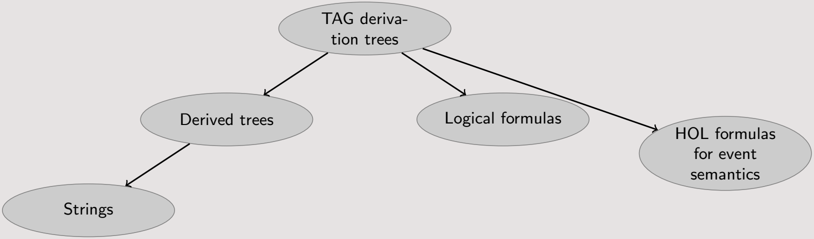
c. Every boy does not want to sleep.

$M_7 = Closure(C_{to\text{-}sleep}\,(C_{wants}\,\mathrm{I}_{\mathbf{S}}\,\mathrm{I}_{\mathbf{VP}}(C_{boy}\,C_{every})))\ :\ \mathbf{T}$

$\forall x(\mathrm{boy}\, x \supset \neg(\exists w(\mathrm{want}\, w) \wedge (arg_0\, w\, x) \wedge (\exists u.(\mathrm{sleep}\, u) \wedge (Arg_1\, w\, u) \wedge (arg_0\, u\, x))))$

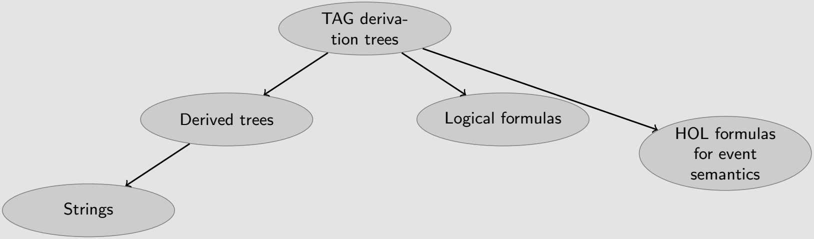
only one reading out of two

Future Work and Conclusion



Current approach

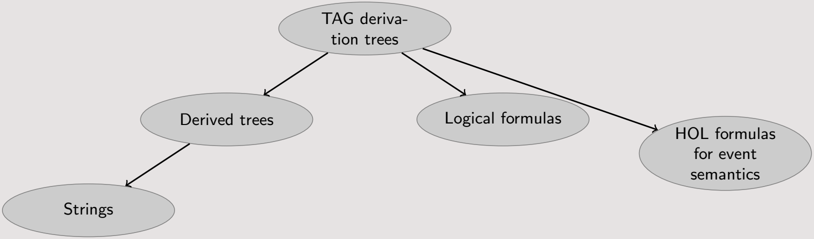
Future Work and Conclusion



Current approach

- TAG derivation trees to Stable's HOL translation of AMRs using ACGs
- Coreference missing in AAMR
- An approach to NLG with HOL encodings of AMRs for free

Future Work and Conclusion



Current approach

- TAG derivation trees to Stable's HOL translation of AMRs using ACGs
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- An approach to NLG with HOL encodings of AMRs for free

Future work

- Encode more complex interaction of quantifiers and negation
- A large scale ACG
- Maintain reasonable bounds on parsing/generation complexity

Thank You

References I

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