Deductive Parsing

WITH AN UNBOUNDED TYPE LEXICON

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Why Parsing?

Compositionality

Meaning of complex expression derived by constituent expressions and their means of interaction.

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Compositionality

Meaning of complex expression derived by constituent expressions and their means of interaction.

Syntax

Algebra of sentence structure

Base for linguistically informed compositional semantics

Why Deductive?

Syntax

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Type-Logical Grammars

Words $\rightarrow$ Logical Formulas

Well-Formedness $\equiv$ Provability

$$\text{Syntax} \xleftrightarrow{\text{TLG}} \text{Logic}$$

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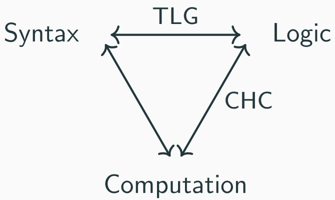
Curry-Howard Correspondence

Logical Formulas $\leftrightarrow$ Typed Variables

Proofs $\equiv$ Functional Programs



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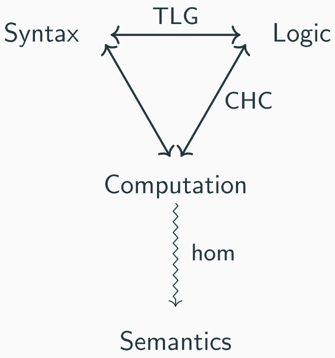
Syntax-Semantics Interface

Syntactic Types $\rightarrow$ Semantic Spaces

Derivations $\rightarrow$ Semantic Programs



A Dependency-Decorated TLG

Lexicon: Words $\rightarrow$ dependency-decorated MILL types (*à la ACG*)

Constants: $\{$ NP, S, PRON $\ldots\}$

Functions: $\{ \diamond^{\mathsf{su}}\text{NP} \rightarrow \text{S}, \diamond^{\mathsf{su}}\text{NP} \rightarrow \left(\diamond^{\mathsf{obj}}\text{NP} \rightarrow \text{S}\right), \ldots\}$

$$\mathcal{T} := A \mid \diamond^{d}\ T_0 \mid T_1 \rightarrow T_2$$

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Parsing: Proof Search

$$\frac{\Gamma \vdash s : A \rightarrow B \quad \Delta \vdash t : A}{\Gamma, \Delta \vdash s\langle t \rangle : B} \rightarrow E \qquad\qquad \frac{\Gamma, x : A \vdash u : B}{\Gamma \vdash \lambda x.u : A \rightarrow B} \rightarrow I$$

Parsing Framework

Parse State

- A logical judgement (premises & conclusion)
- Word associations for (some) premise formulas
- A single element stack

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Framework

Given a parse state

1. Decide between introduction $\oplus$ elimination
2. Perform either
3. Update state(s)
4. Repeat

Ambiguities (the bad kind)

$$\mathcal{L} := \{\text{"}\textit{ducks}\text{"}: \textsc{np},\ \text{"}\textit{eat}\text{"}: \diamond^{\mathsf{su}}\textsc{np} \rightarrow \left(\diamond^{\mathsf{obj}}\textsc{np} \rightarrow \textsc{s}\right),\ \text{"}\textit{seeds}\text{"}: \textsc{np}\}$$

$$\text{"}\textit{ducks eat seeds}\text{"} \vdash^{?} \textsc{s}$$

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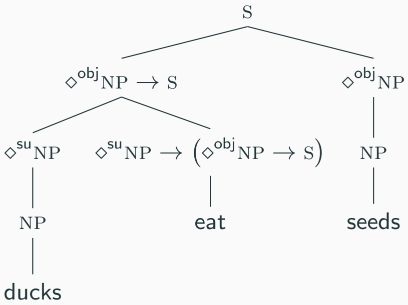

`(eat seeds) ducks` ✓

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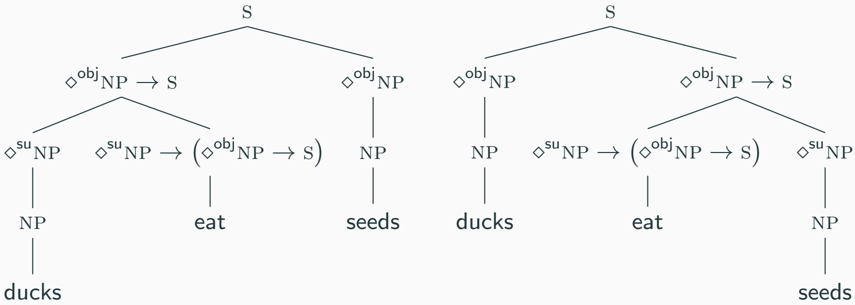

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Resolving Ambiguities

Key insight

Structure can be disambiguated by utilizing word and position information on top of types.

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Words (& Position)

Contextualized embeddings from some LM

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Types

Type-level recursive GRU

$$\lceil A \rceil = \overrightarrow{A}$$

$$\lceil \diamond^d X \to Y \rceil = GRU\left(\left[\overrightarrow{d}, \lceil X \rceil, \lceil Y \rceil\right]\right)$$

Elimination $\sim$?

Problem

Given a *judgement*, decide between possible *branchings*..

Elimination $\sim$?

Problem

Given a *judgement*, decide between possible *branchings*..

.. given a sequence of *word & type pairs*, assign each item a *binary label*

Elimination ∼ Binary Classification

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Given a *judgement*, decide between possible *branchings*..

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Binary Sequence classification (Deep bi-GRU)

- **Input**: Sequence of word & type vectors (conc.)
- **Output**: Sequence of binary labels

Proof Traversal

$$\dfrac{\dfrac{\dfrac{}{\text{eat} \vdash \mathrm{NP} \to \mathrm{NP} \to \mathrm{S}}\ Ax. \qquad \dfrac{}{\text{seeds} \vdash \mathrm{NP}}\ Ax.}{\text{eat}, \text{seeds} \vdash \mathrm{NP} \to \mathrm{S}} \to E \qquad \dfrac{}{\text{ducks} \vdash \mathrm{NP}}\ Ax.}{\text{ducks}, \text{eat}, \text{seeds} \vdash \mathrm{S}}$$

Deep bi-GRU

$$\left(\overrightarrow{\text{ducks}}; \lceil \mathrm{NP} \rceil\right), \quad \left(\overrightarrow{\text{eat}}; \lceil \mathrm{NP} \to \mathrm{NP} \to \mathrm{S} \rceil\right), \quad \left(\overrightarrow{\text{seeds}}; \lceil \mathrm{NP} \rceil\right) \vdash \lceil \mathrm{S} \rceil$$

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↑

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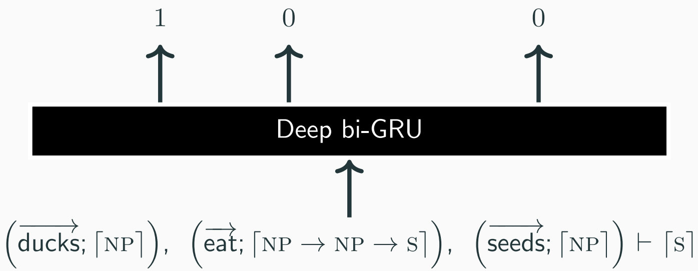

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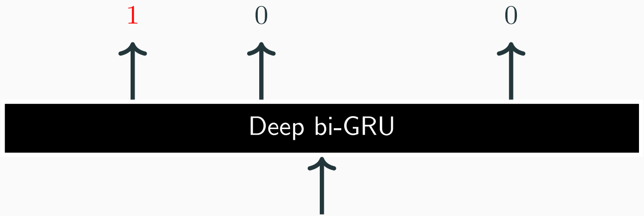

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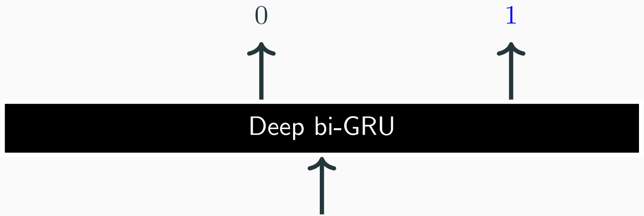

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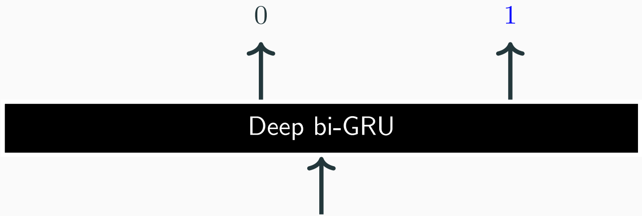

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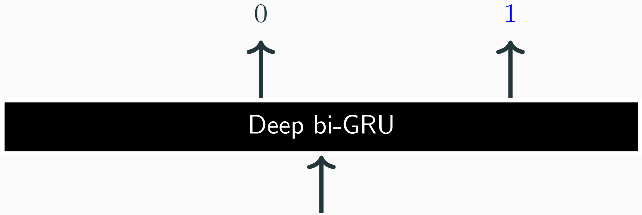

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Training sample	:	Junction point	Massive Parallelism
Sentence	:	N independent samples	

..but is it working?

Some Concessions

- Up to 2nd order types
- No conjunctions
- Gold types as input

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Table with Numbers

Input	*Accuracy*
Types & Words & Goal	**97.2**
Types & Words	95.3
Types only	94.2
Words only	87.7

Conclusion & Future

Neural TLG Parsing

- Fast & Efficient
- Accurate
- Formally grounded
- Ideal for semantic tasks

 # todo

- End-to-end integration & evaluation
- Higher-order structures
- Other approaches (.. Shift-Reduce, ProofNets?)

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