A Relational Syntax-Semantics Interface Based on Dependency Grammar

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Overview

1. *Background and Motivation*
2. Extensible Dependency Grammar
3. A Relational Syntax-Semantics Interface
4. Summary and Future Work

Background

- the traditional perspective on the syntax-semantics interface is *functional*, i.e. semantic representations are obtained from the syntax tree by structural induction
- but some phenomena (e.g. scope, anaphora) are *not functional*: *one* syntax tree has *several* readings

Some Approaches

- *Categorial Grammar* recasts *semantic ambiguity as syntactic ambiguity* (Montague 1974, Steedman 1999, Moortgat 2002)
- *GB* assumes a *non-deterministic mapping* from syntax to semantics (“Logical Form”) (Chomsky 1986)
- *LFG* makes use of *functional uncertainty* to allow for a restricted form of relationality (Bresnan/Kaplan 1982, Kaplan/Maxwell III 1988)
- *Underspecification* restores functionality by making the semantics less ambiguous, e.g. *MRS*, *CLLS* (Copestake et al. 2004, Egg et al. 2001)

This talk

- we present a *completely relational syntax-semantics interface*
- formalized using *Extensible Dependency Grammar* (XDG)
- the *XDG solver* for parsing supports the *concurrent* flow of possibly partial information such that syntax and semantics can *mutually constrain each other*

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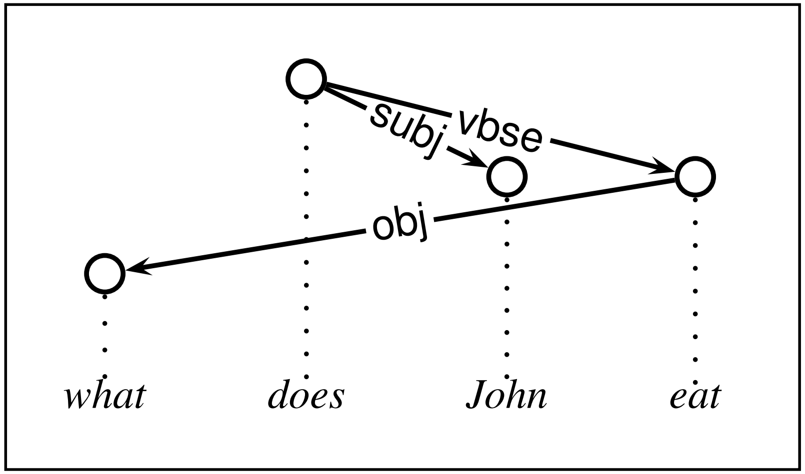
Extensible Dependency Grammar

- XDG is a *graph description language* designed for the dependency-based modeling of natural language, based on Topological Dependency Grammar (TDG) (Duchier/Debusmann 2001)
- an XDG *analysis* involves arbitrary many *graph dimensions* sharing the same set of nodes, but having different edges
- XDG is *strongly lexicalized*, and has a *powerful lexicon language* supporting e.g. lexical inheritance a la HPSG

An Example Analysis



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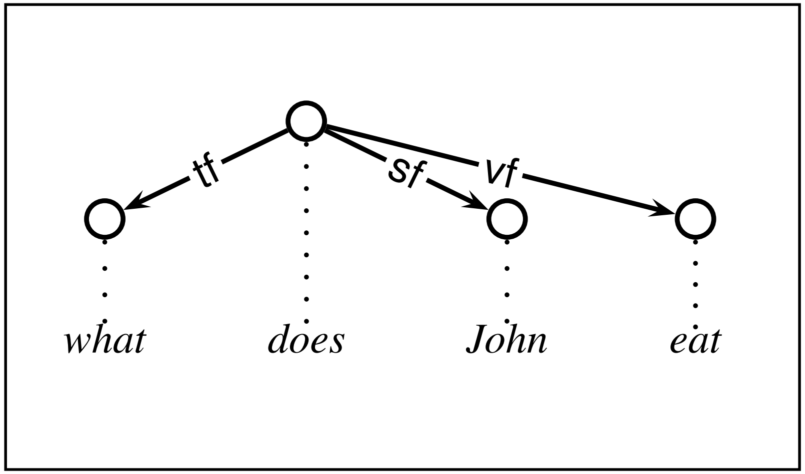
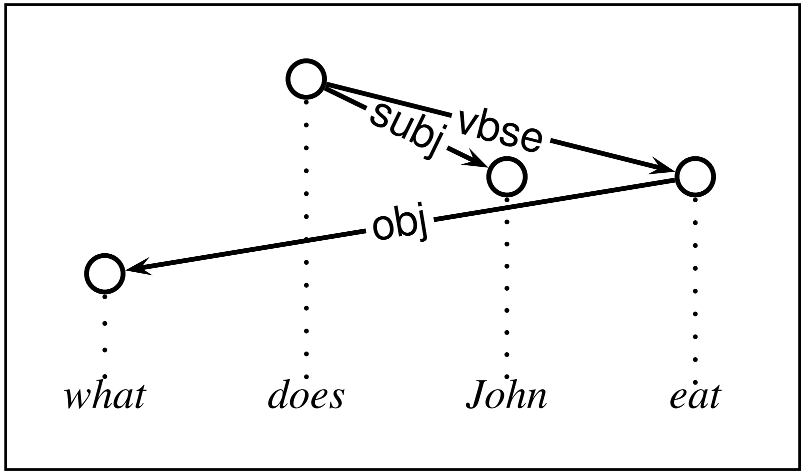


Linear Precedence (LP)

Principles

- *principles* determine the *well-formedness conditions* of XDG analyses, constraining:
  - global properties of graphs (e.g. treeness)
  - local properties of nodes (e.g. valency)
  - structural relations between graphs (e.g. climbing)
- the latter is done by *multi-dimensional principles*, as opposed to *one-dimensional principles*

Treeness Principle



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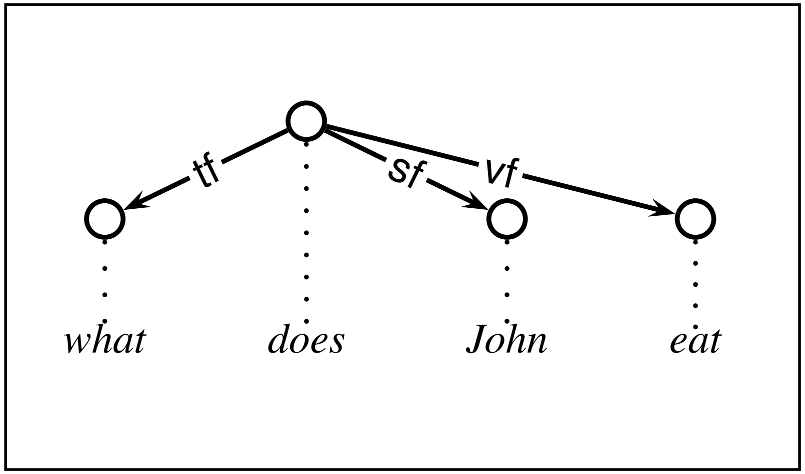
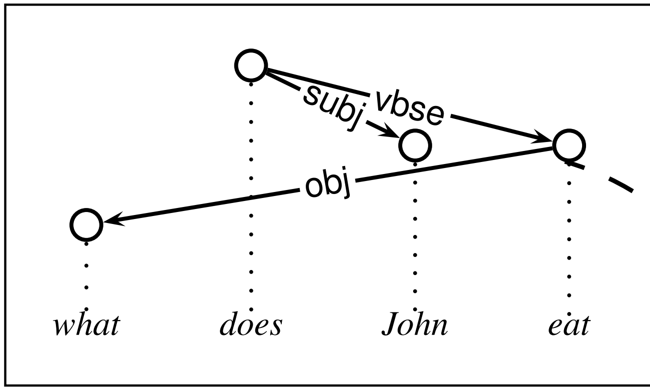


Linear Precedence (LP)

- both graphs must be trees

Valency Principle



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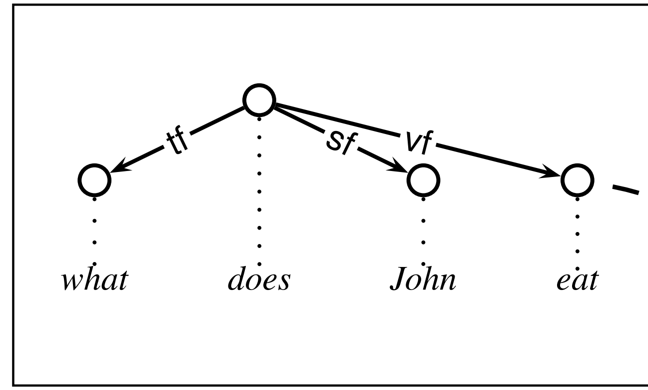


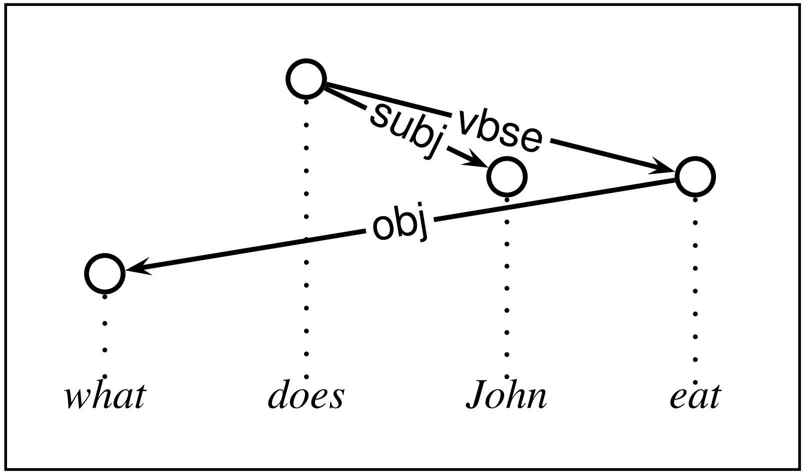
Linear Precedence (LP)

[in: {vbse?}
out: {obj!}]

[in: {vf?}
out: {}]

- both graphs must satisfy the in and out specifications in the lexicon

Order Principle



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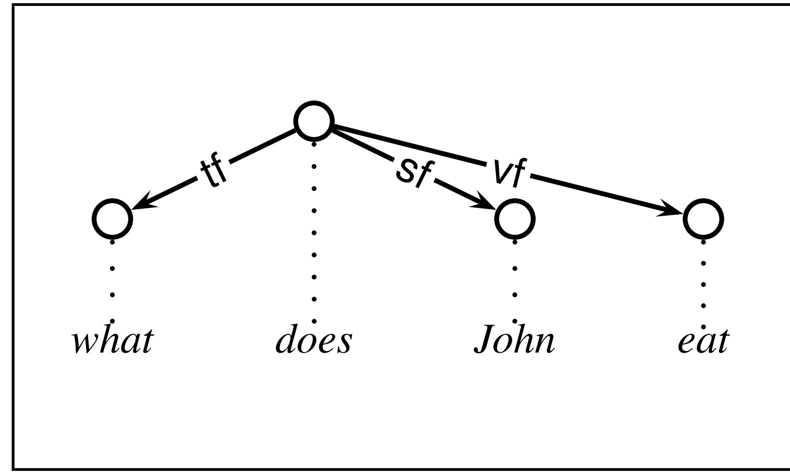
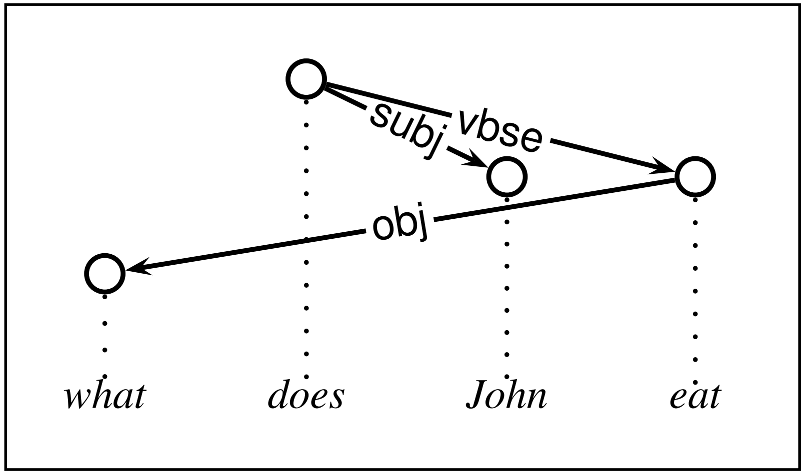


Linear Precedence (LP)

- the LP tree is ordered and projective (the ID tree is unordered)
- here: $tf \prec sf \prec vf$

Climbing Principle



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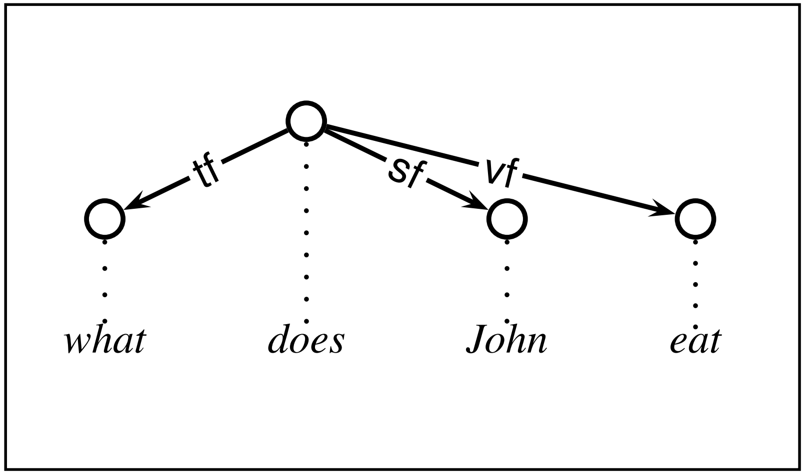

Linear Precedence (LP)

- the LP tree must be a flattening of the ID tree
- Also called *lifting* or *emancipation* (Kahane et al. 1998, Gerdes/Kahane 2001)

Processing

- the *XDG solver* implements an axiomatization of XDG as a *constraint satisfaction problem* (Duchier 1999, Duchier 2003)
- XDG solver can be used both for *parsing* and *generation*
- all dimensions are processed *concurrently*
- *partial analyses* can be extracted at each point during solving
- solving *efficient* for *small handcrafted grammars*
- solving of *large grammars work in progress*

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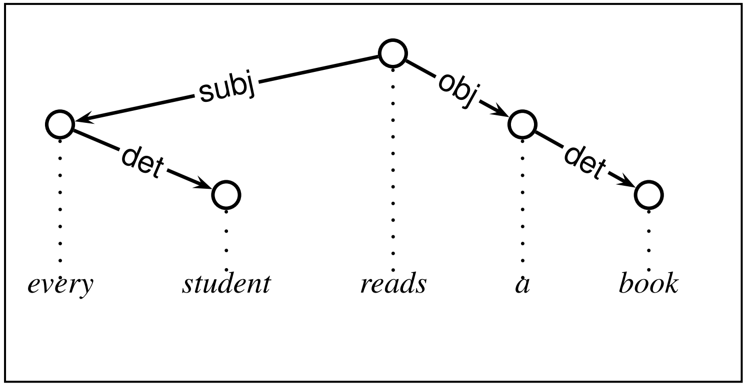
Ingredients

- *Immediate Dominance* tree (ID)
- *Linear Precedence* tree (LP)
- *Predicate-Argument* structure (PA)
  - models *variable binding*
  - resolves e.g. *raising and control constructions*
- *Scope tree* (SC)
  - models the *scopal relationships*, i.e. the structure of the reading
  - can be likened with the TAG *derivation tree*, reflecting how semantic building blocks are put together

An Example



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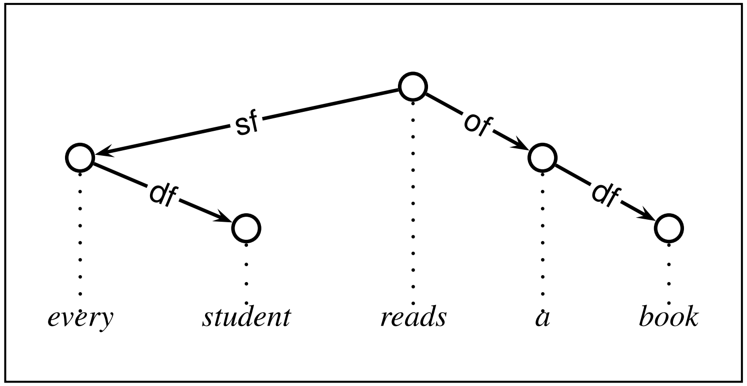

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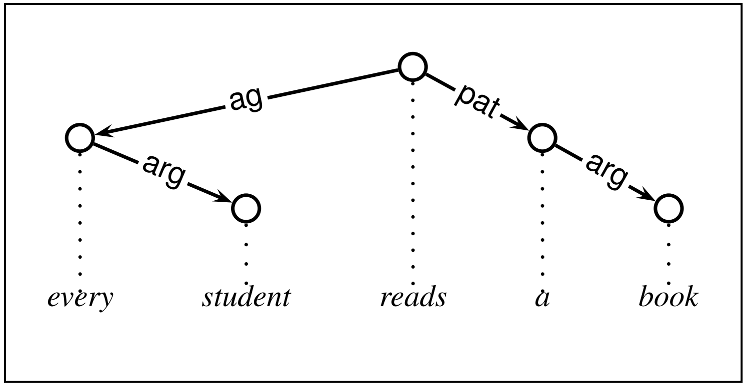

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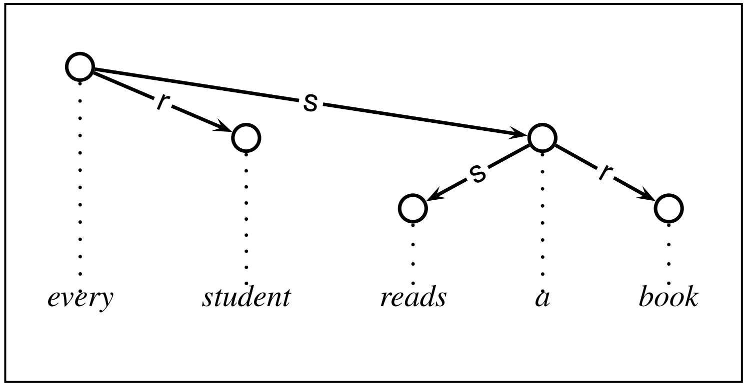
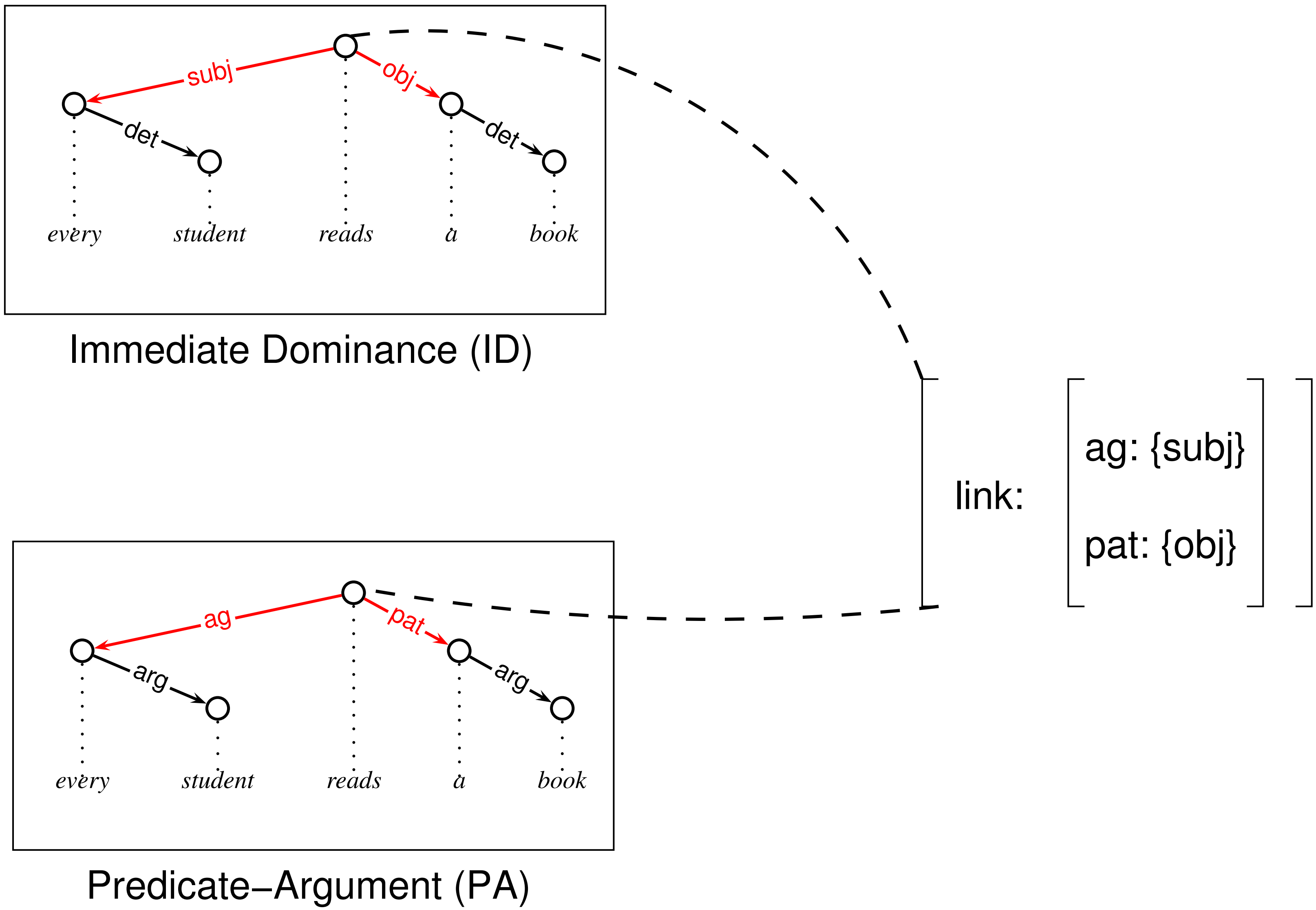


Scope (SC)

Linking Principle

- *multi-dimensional*
- used to state how *semantic arguments* are *realized* in the *syntax*
- *lexicalized*, i.e. capable of handling alternations

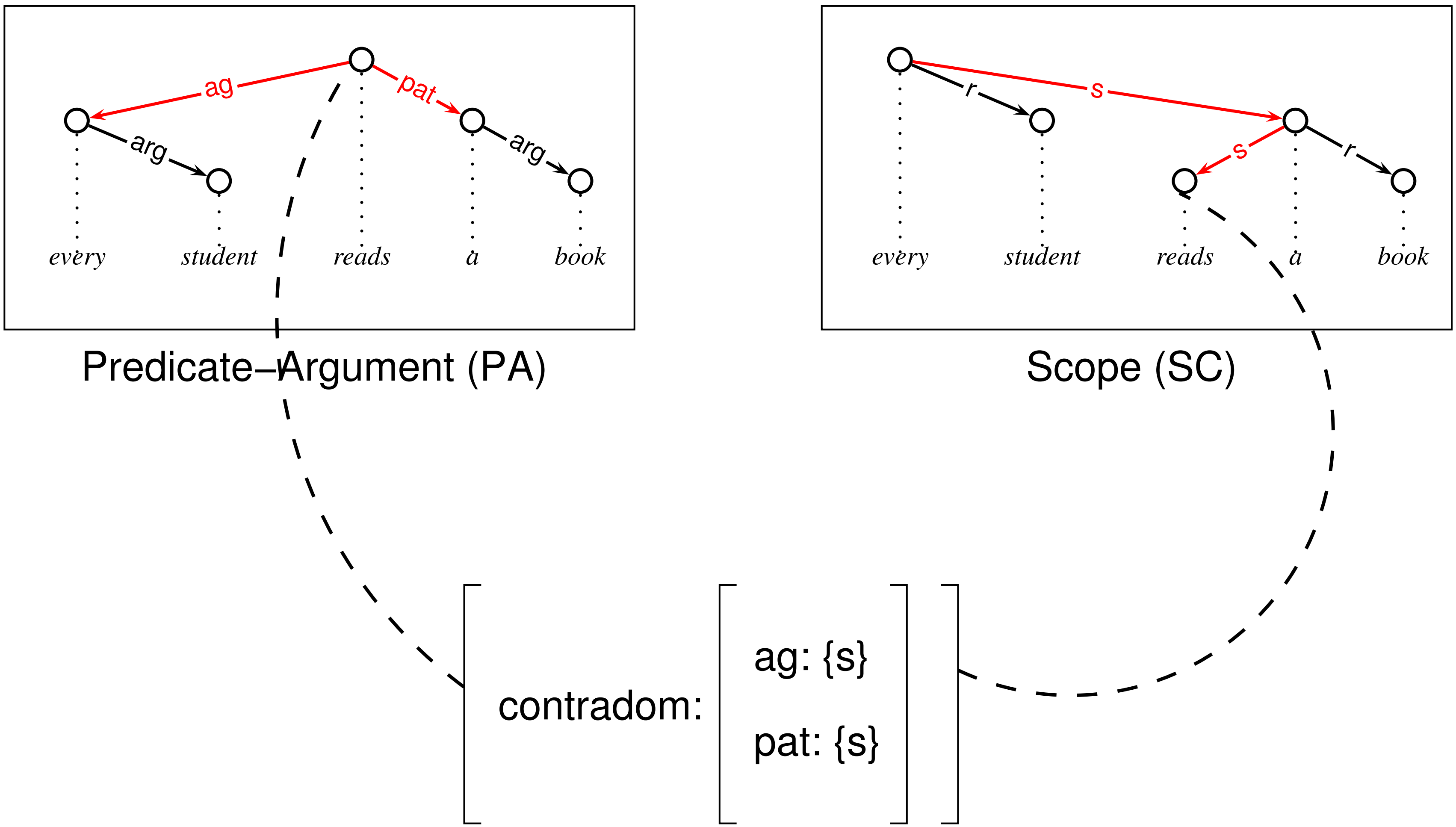
Linking Example



Contra-Dominance

- *multi-dimensional*
- used to constrain the relation between the Predicate-Argument structure and the Scope tree
- also lexicalized

Contra-Dominance Example



Interpretation

- we can translate *XDG analyses* into standard *type-theoretical expressions* (Montague 1974)
- the *Predicate-Argument structure* determines *variable binding*
- the *Scope tree* determines the *structure* of the reading

Interpretation functions

- $L(v)$ *lexical semantic value* of node v
- $P(v)$ *phrasal semantic value* of the entire subtree rooted at v

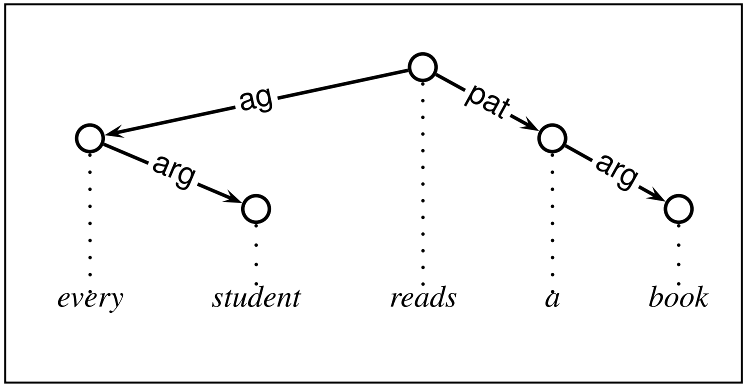
An Example Semantic Lexicon

- $\mathcal{L}(\text{“}\textit{every}\text{”}) = \lambda P \lambda Q \lambda e. \forall x (\mathcal{P}(x) \rightarrow Q(x)(e))$
- $\mathcal{L}(\text{“}\textit{a}\text{”}) = \lambda P \lambda Q \lambda e. \exists x (\mathcal{P}(x) \wedge Q(x)(e))$
- $\mathcal{L}(\text{“}\textit{student}\text{”}) = \textit{student'}$
- $\mathcal{L}(\text{“}\textit{book}\text{”}) = \textit{book'}$
- $\mathcal{L}(\text{“}\textit{reads}\text{”}) = \textit{read'}(\downarrow \textit{pat})(\downarrow \textit{ag})$

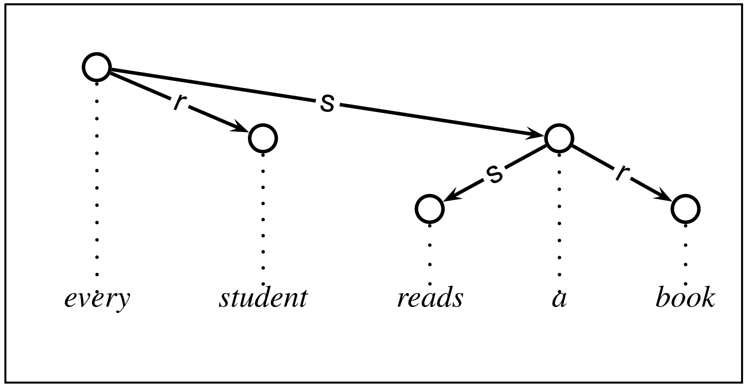
The Phrasal Semantic Value

- $\mathcal{P}(\text{“every”}) = \mathcal{L}(n)(\mathcal{P}(\downarrow \text{r}))(\lambda \downarrow n.\mathcal{P}(\downarrow \text{s}))$
- $\mathcal{P}(\text{“a”}) = \mathcal{L}(n)(\mathcal{P}(\downarrow \text{r}))(\lambda \downarrow n.\mathcal{P}(\downarrow \text{s}))$
- $\mathcal{P}(\text{“student”}) = \mathcal{L}(\text{“student”})$
- $\mathcal{P}(\text{“book”}) = \mathcal{L}(\text{“book”})$
- $\mathcal{P}(\text{“reads”}) = \mathcal{L}(\text{“reads”})$

An Example



Predicate–Argument (PA)



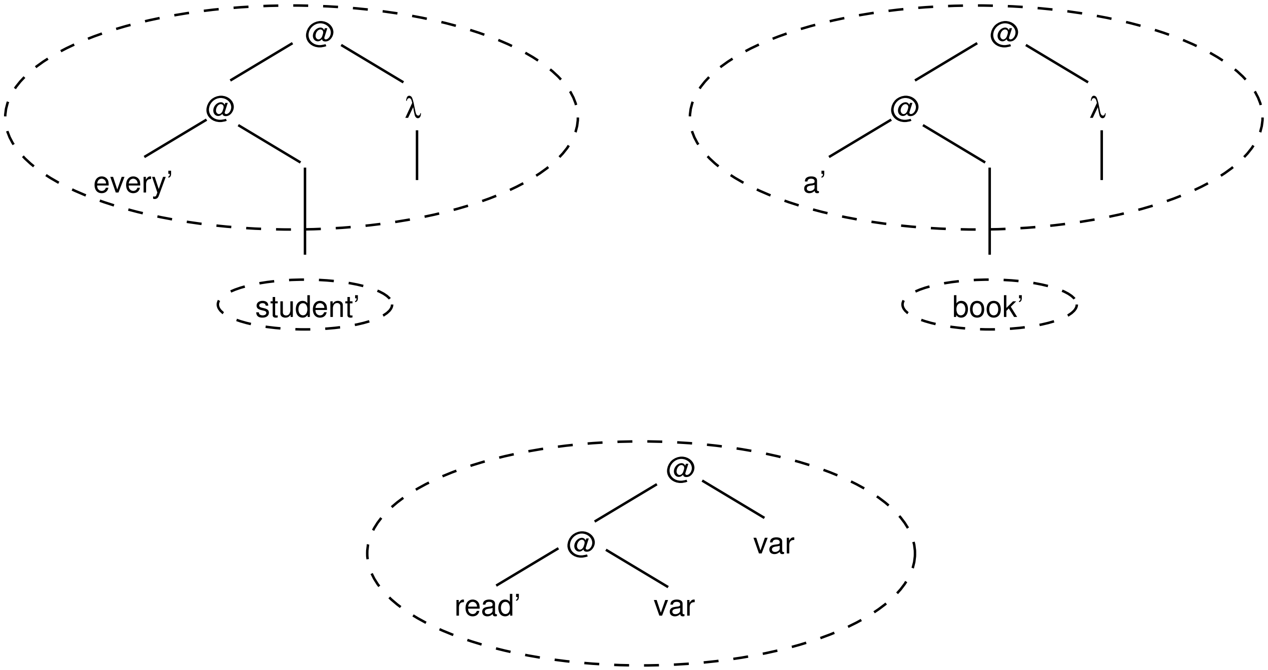
Scope (SC)

$$\mathcal{P}(\text{“every”}) = \ldots =$$
$$\mathcal{L}(\text{“every”})(\mathcal{L}(\text{“student”}))(\lambda x.\mathcal{L}(\text{“a”})(\mathcal{L}(\text{“book”}))(\lambda y.\text{“read’”}(y)(x))) = \ldots =$$
$$\lambda e.\forall x.\text{student'}(x) \rightarrow \exists y.\text{book'}(y) \wedge \text{read'}(y)(x)(e)$$

Underspecification

- the Montague-style interpretation presupposes *completely specified analyses*
- we can reformulate the interpretation to support an extraction of *underspecified semantic descriptions* from *partial analyses*
- idea: associate lexical entries with *partial tree descriptions* a la CLLS (Egg et al. 2001)
- the *Predicate-Argument* structure again contributes the variable bindings
- partial information from the *Scope tree* contributes *additional dominance edges*

An Example



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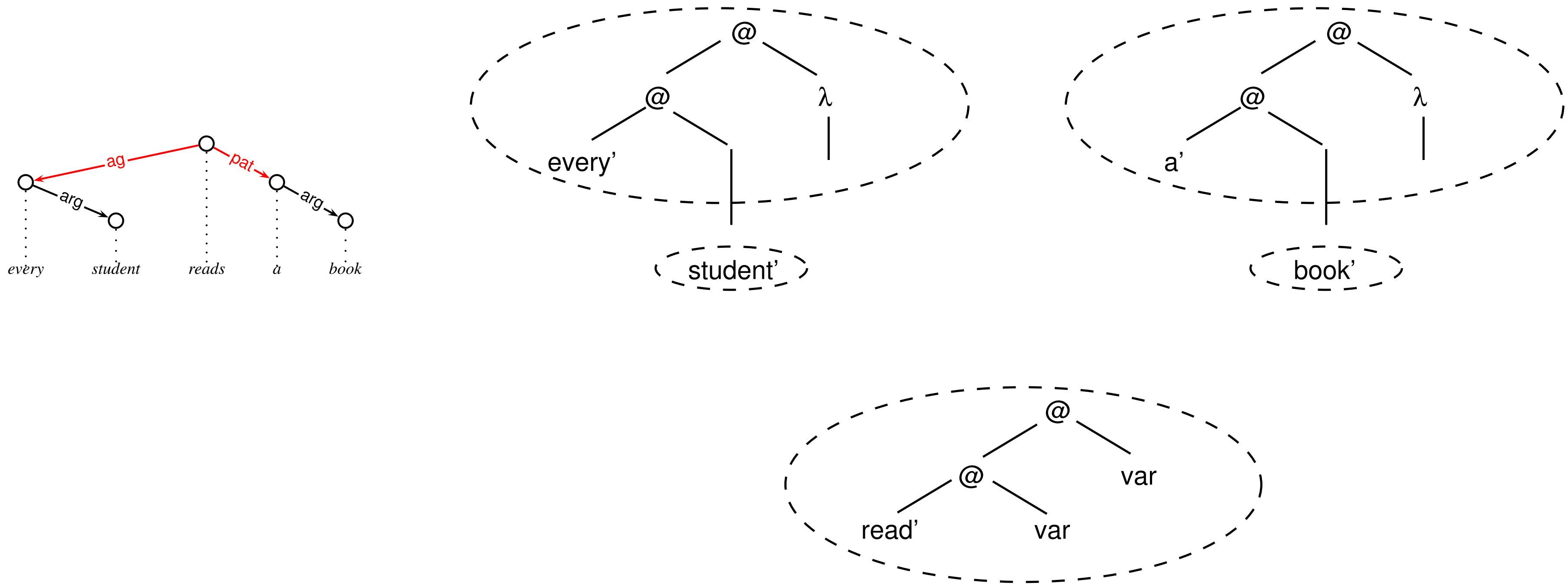
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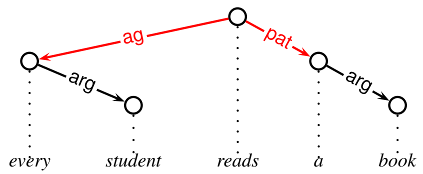
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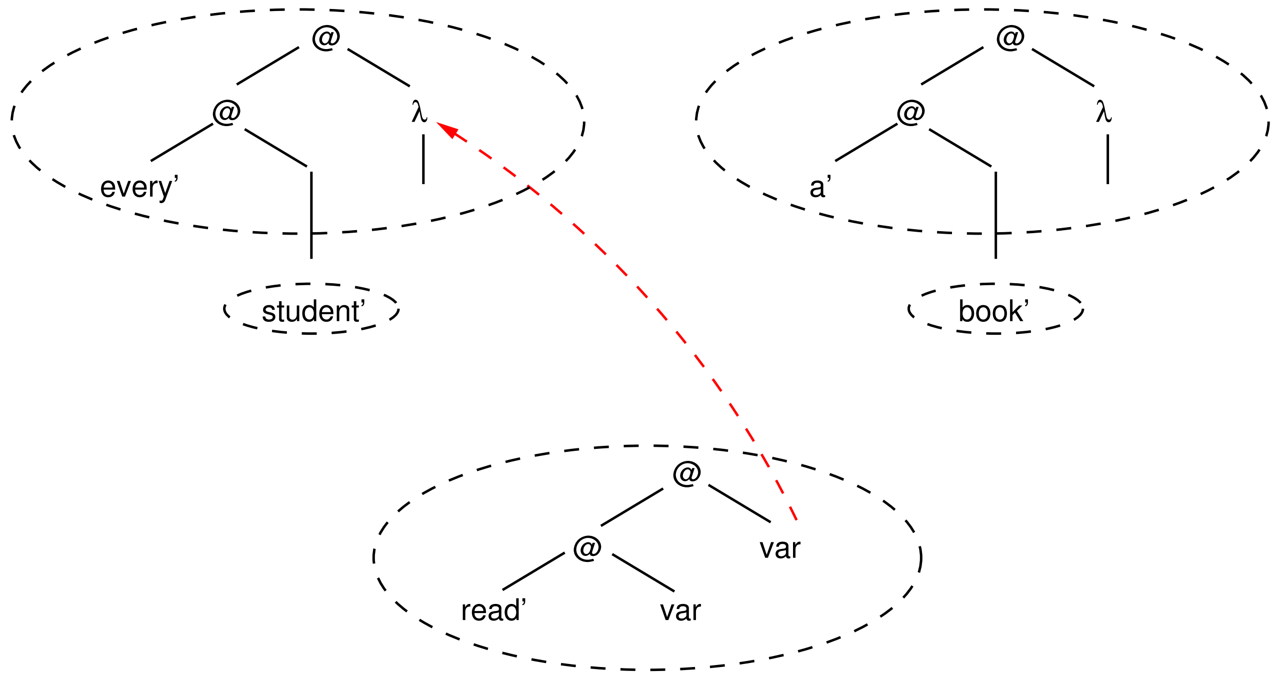
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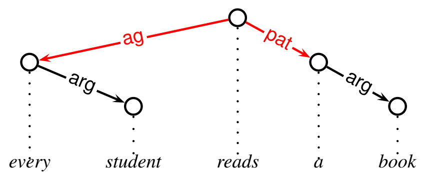
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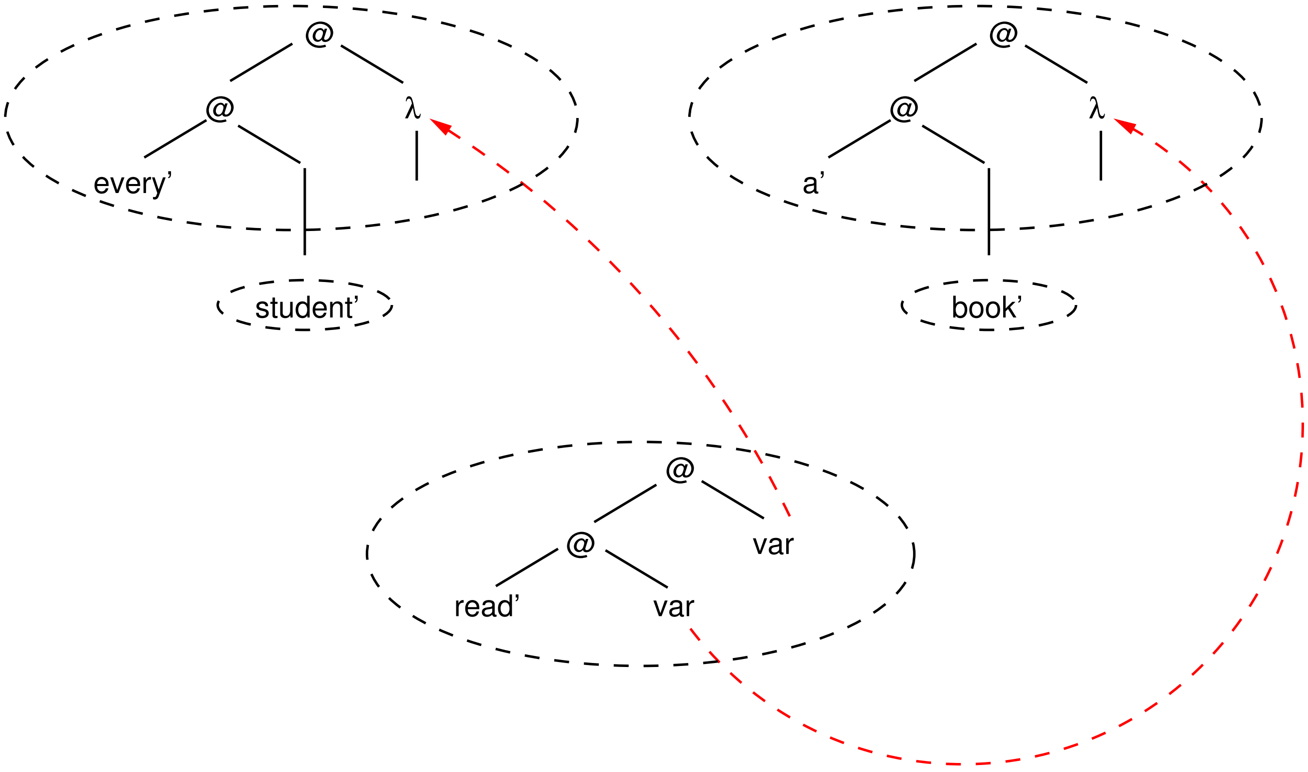
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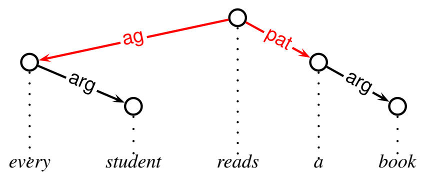

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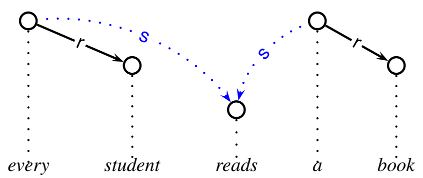

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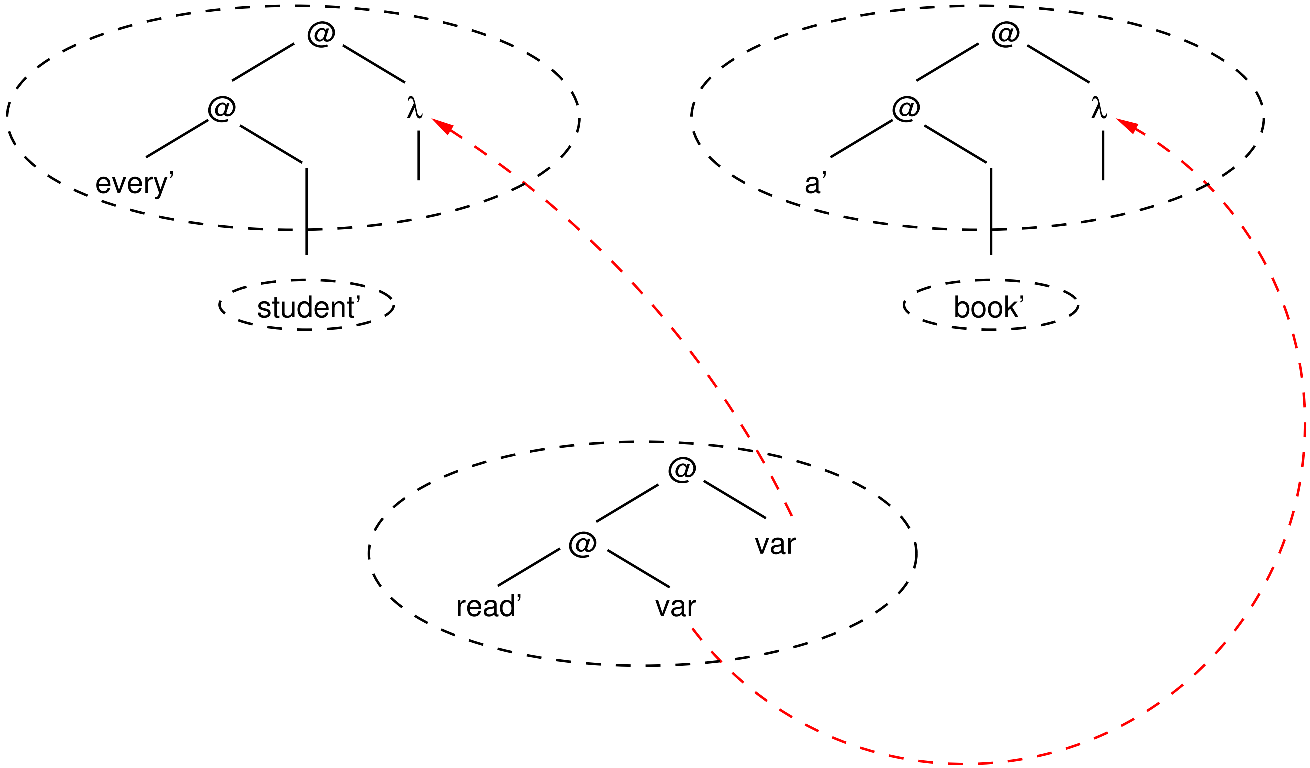

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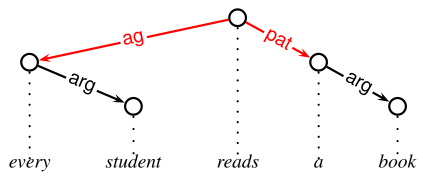
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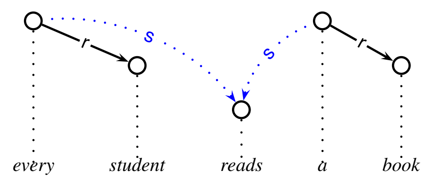
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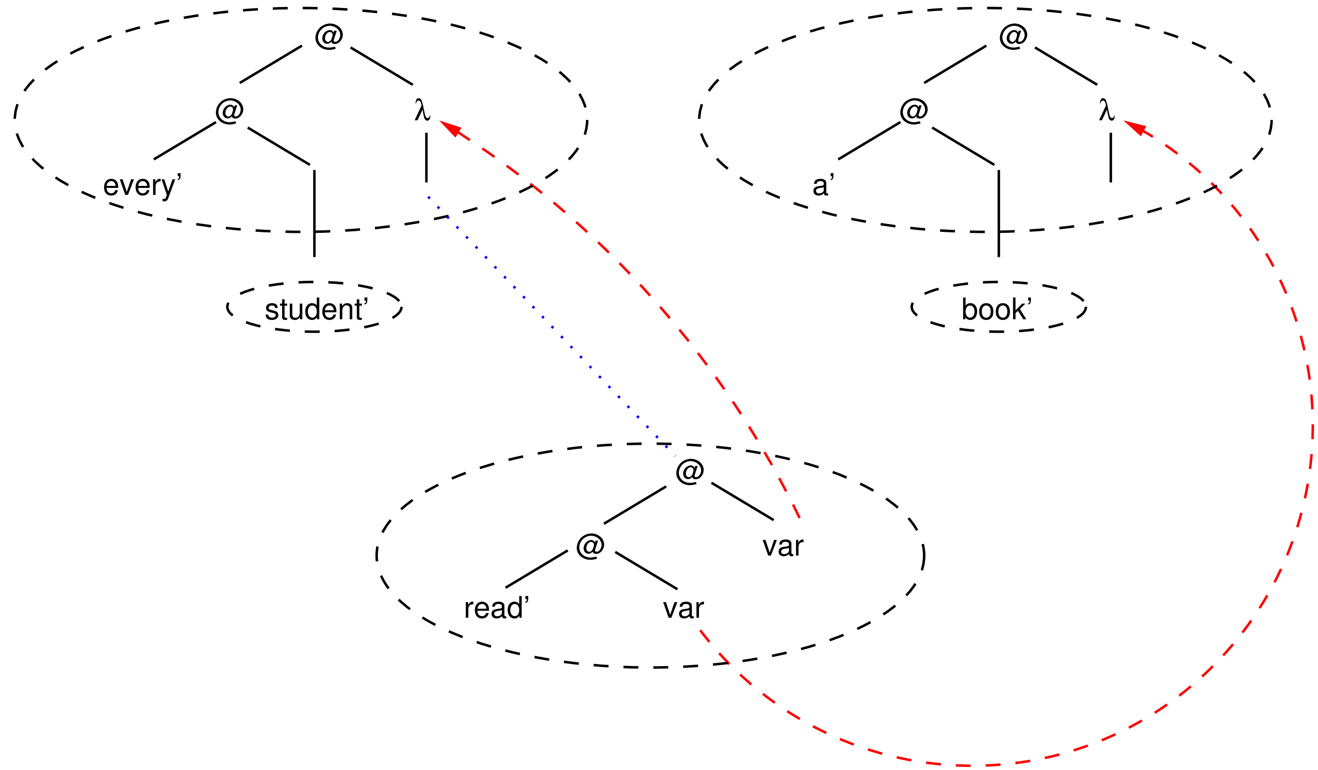
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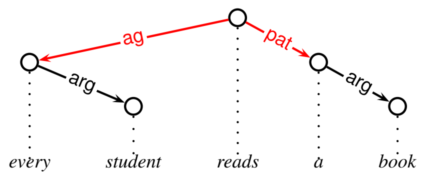

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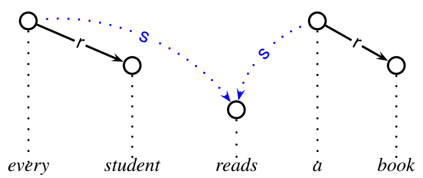

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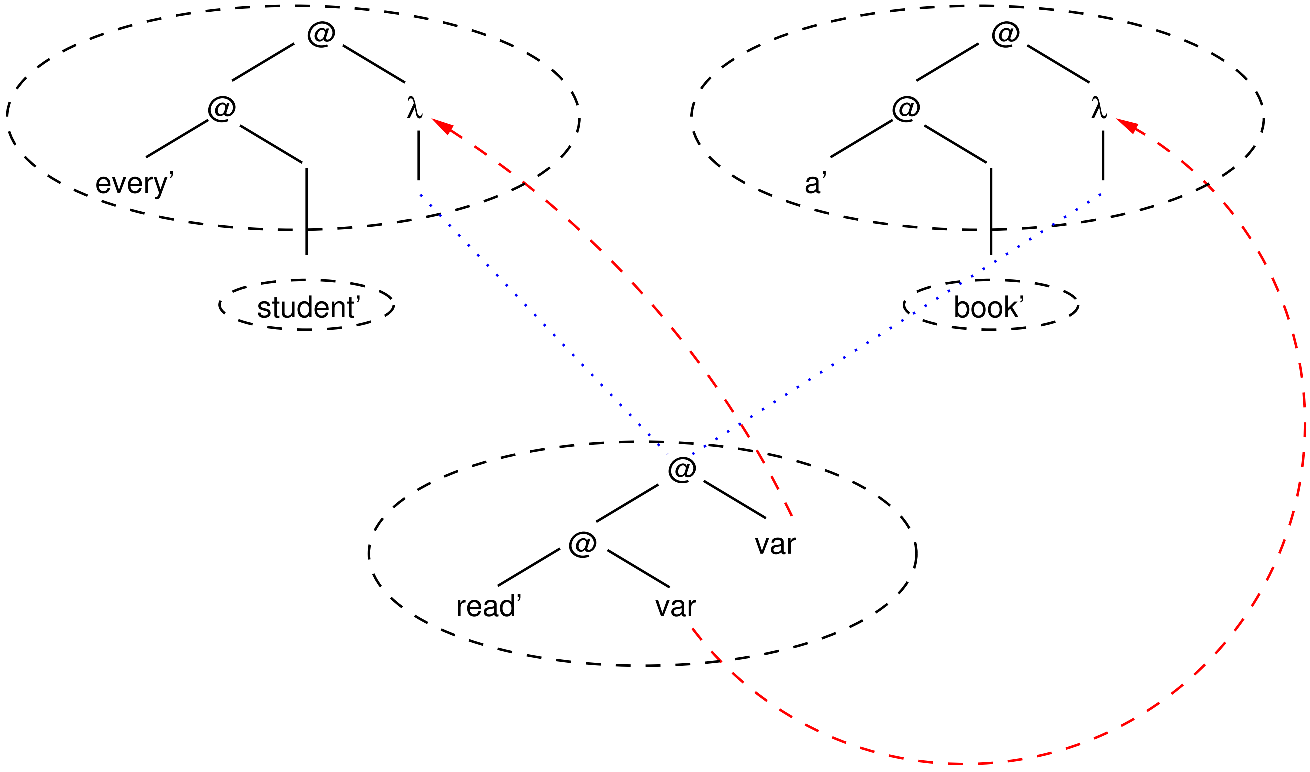

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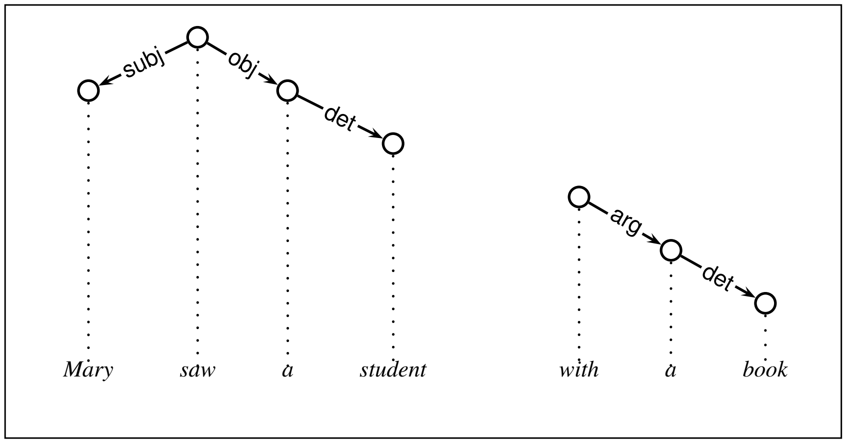
Interaction of Syntax and Semantics

- the relational syntax-semantics interface allows for *inferences from the syntax* to *disambiguate semantics*
- and also vice versa, i.e. *inferences from semantics* can *disambiguate syntax*

Inferences from syntax to semantics



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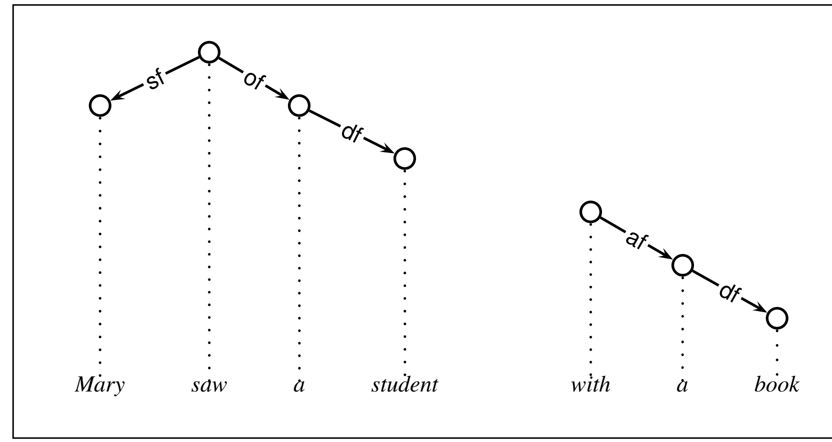

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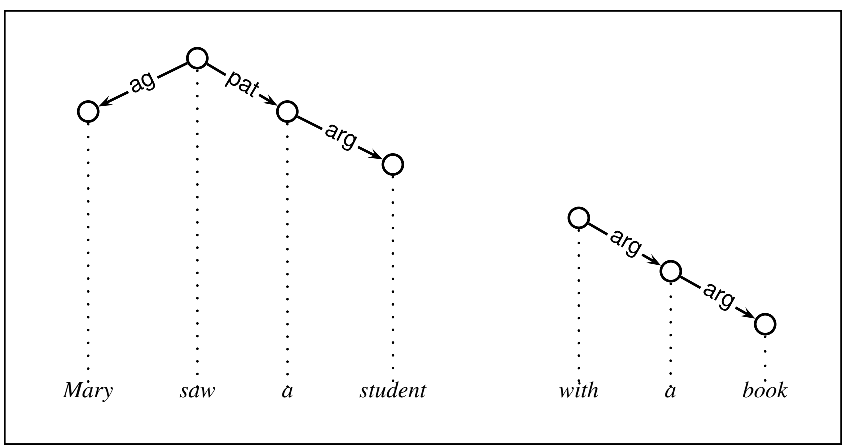

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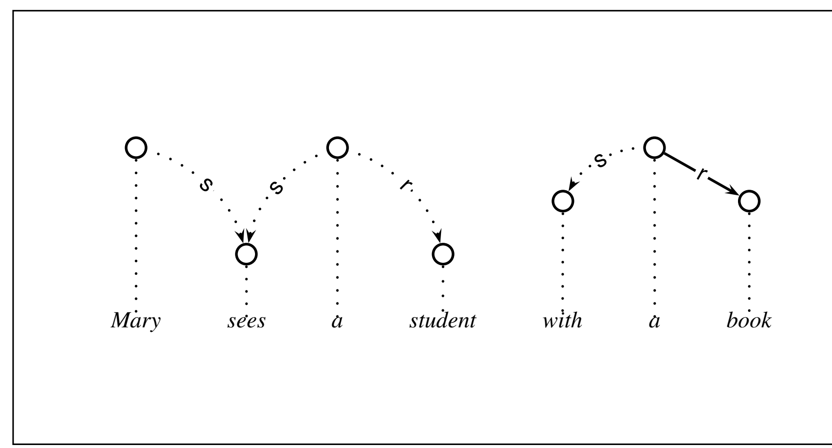
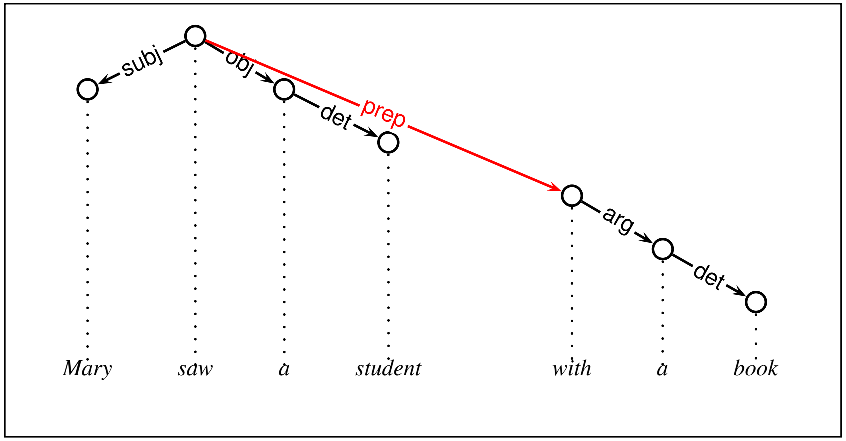


Scope (SC)

Inferences from syntax to semantics



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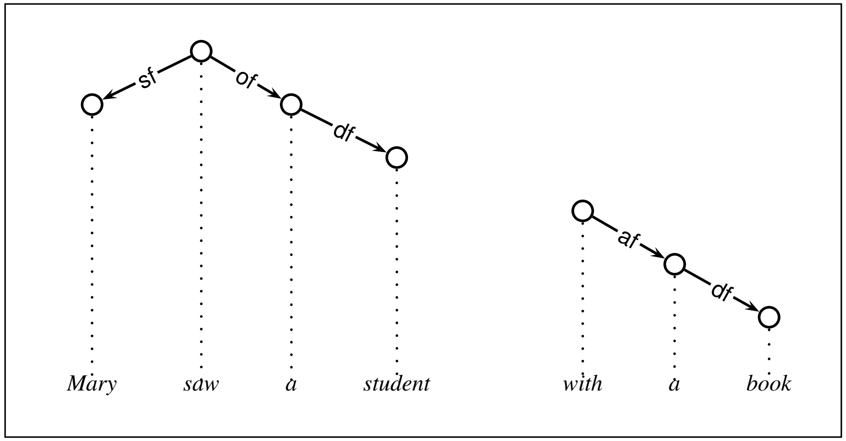

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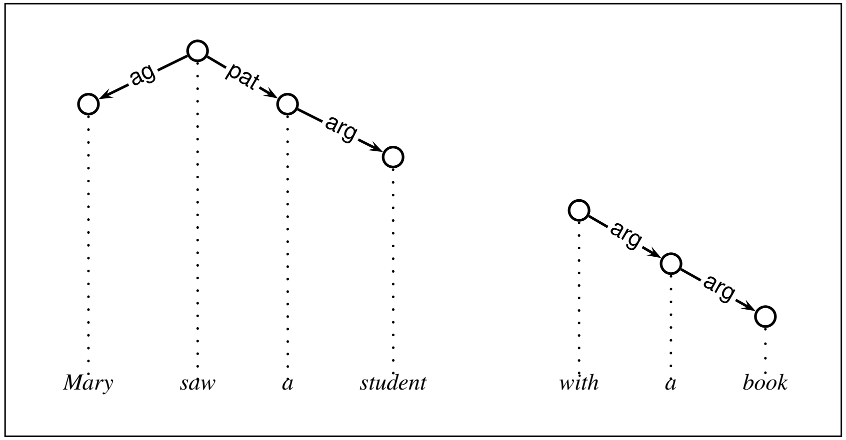

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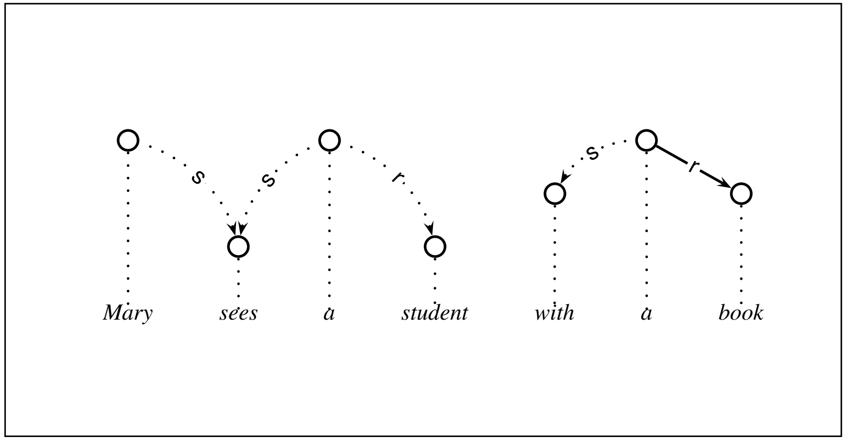

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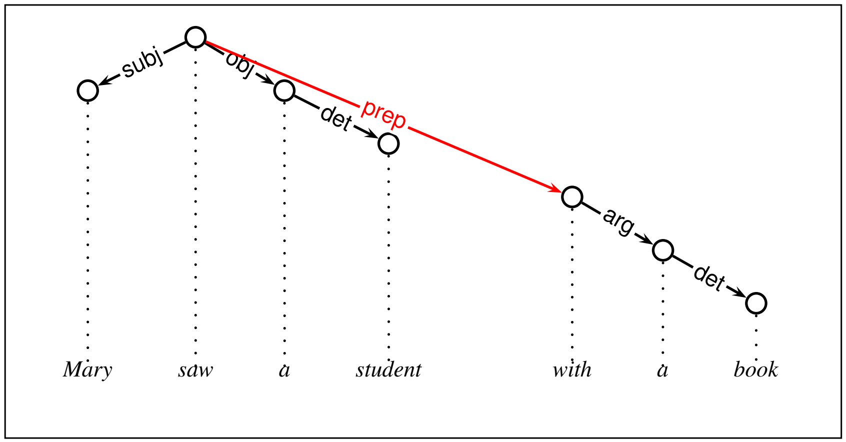

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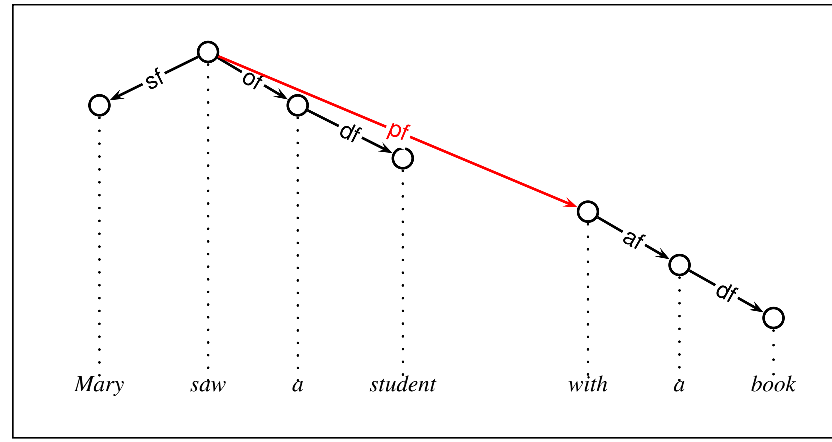

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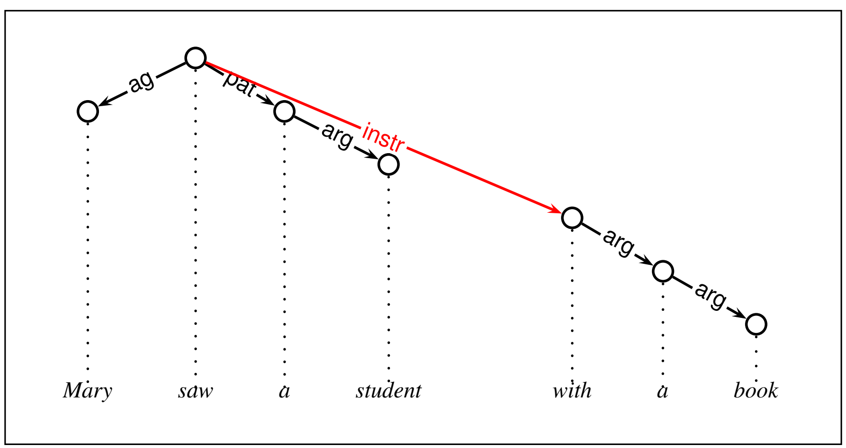

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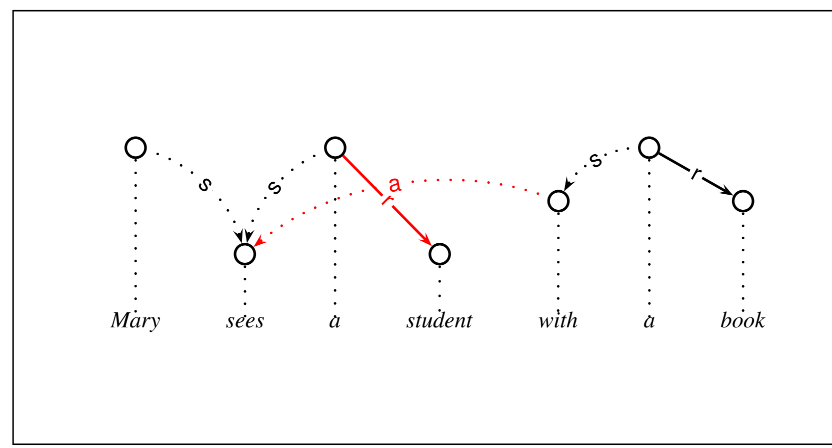
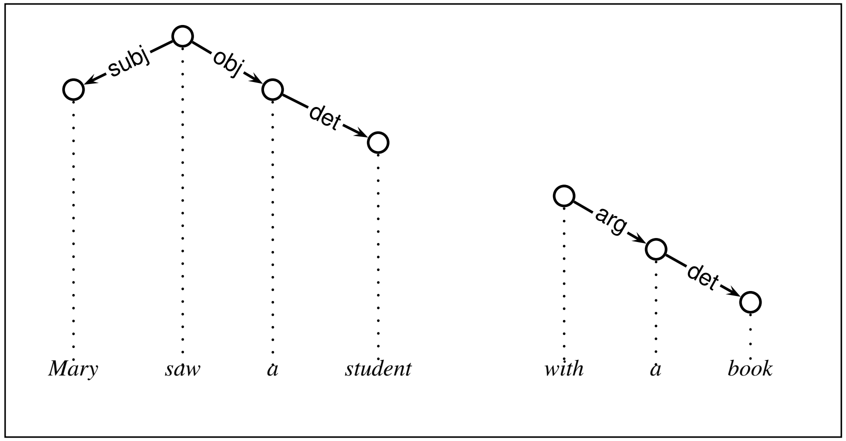


Scope (SC)

Inferences from semantics to syntax



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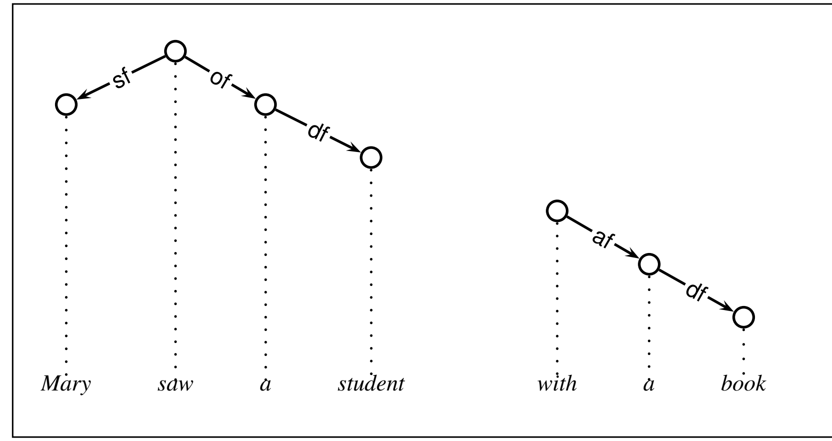

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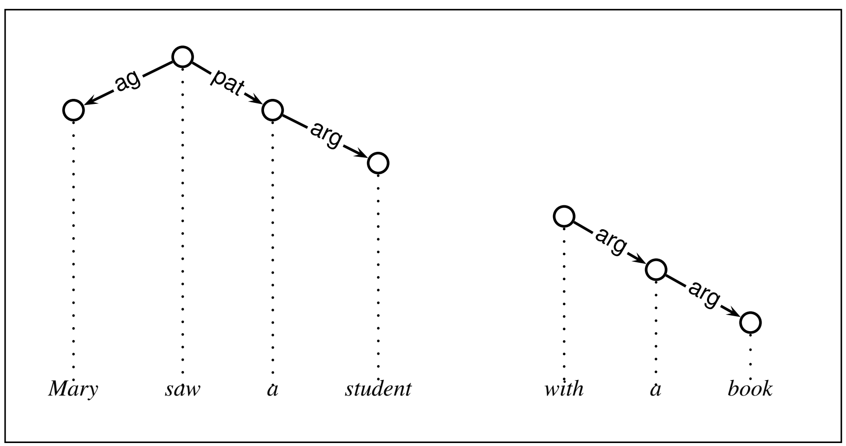

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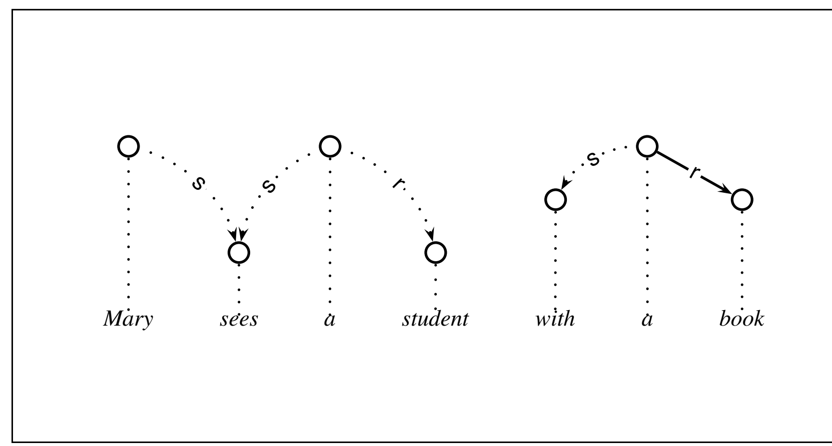
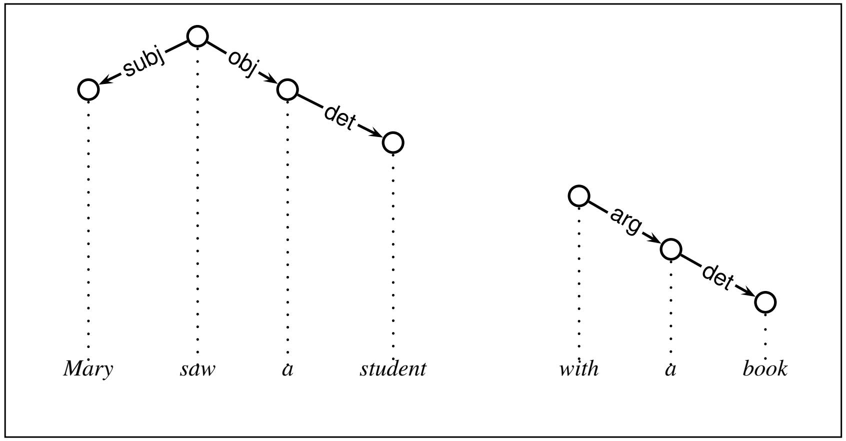
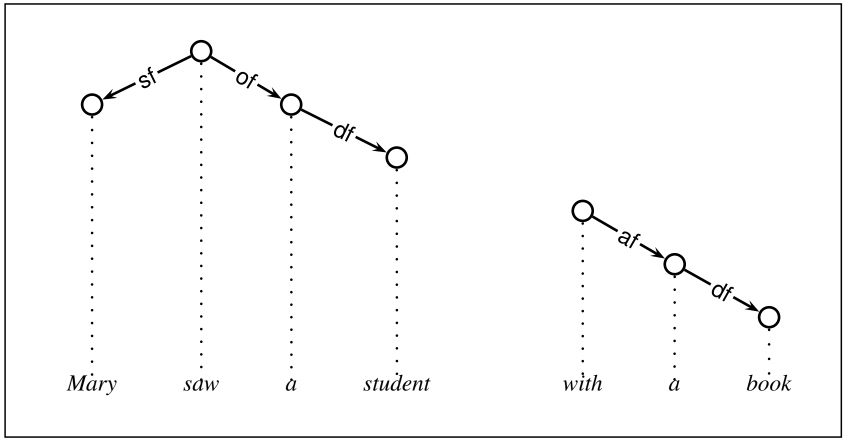


Scope (SC)

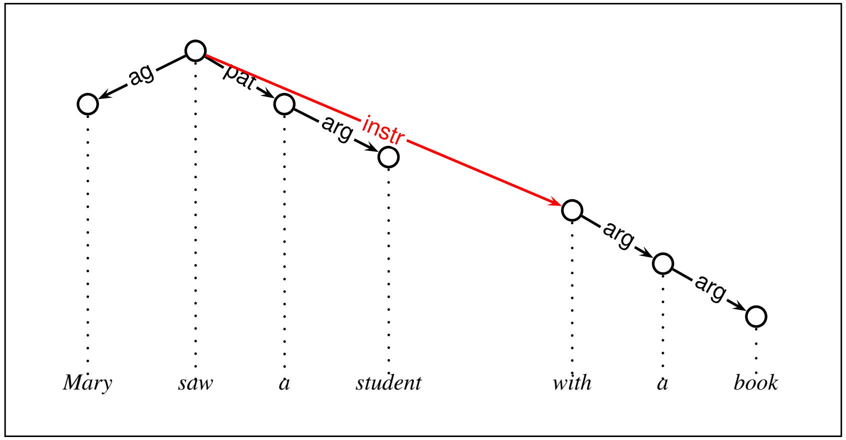
Inferences from semantics to syntax



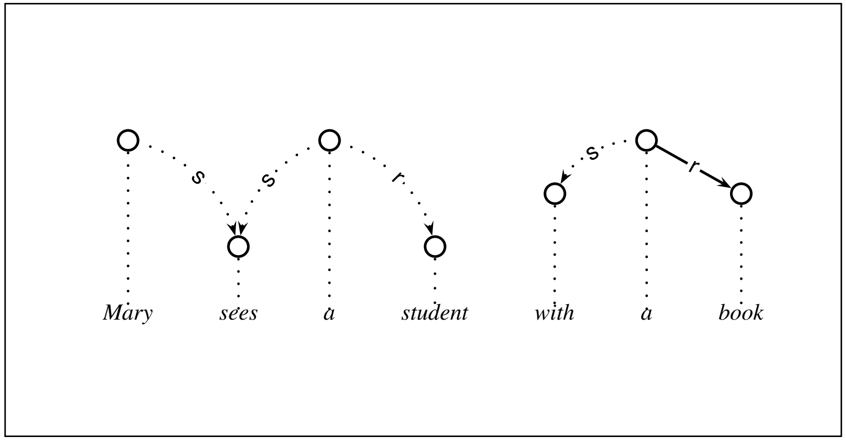
Immediate Dominance (ID)



Linear Precedence (LP)

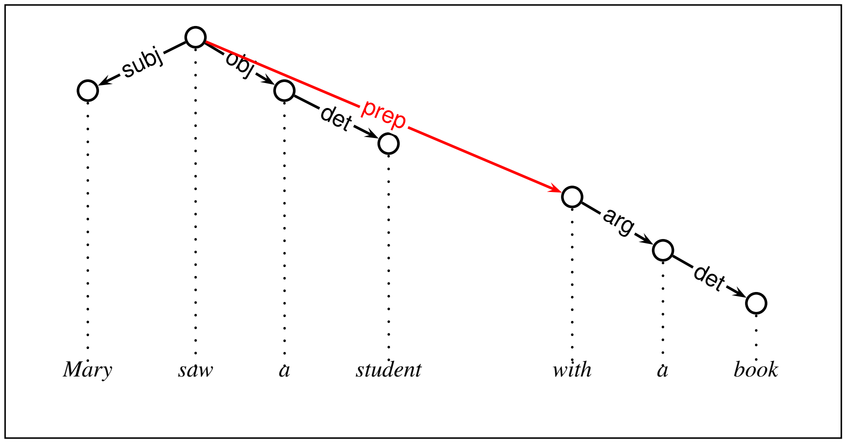


Predicate–Argument (PA)



Scope (SC)

Inferences from semantics to syntax



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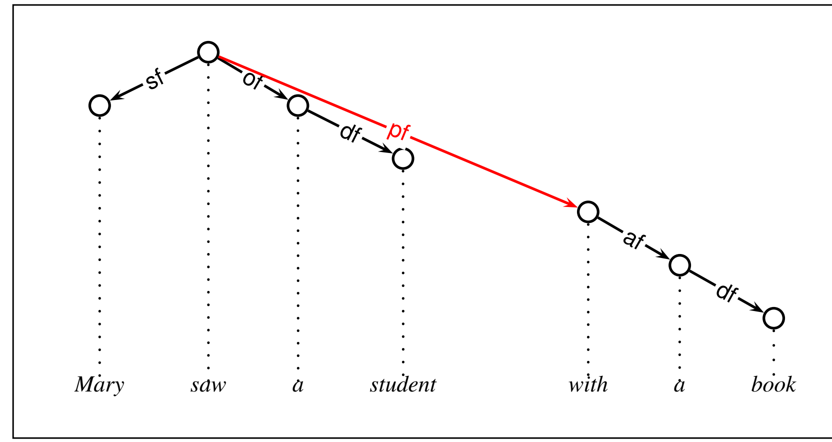
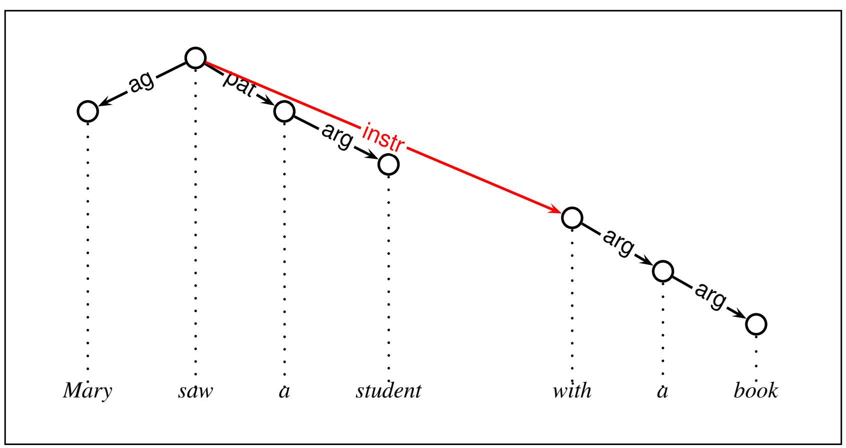
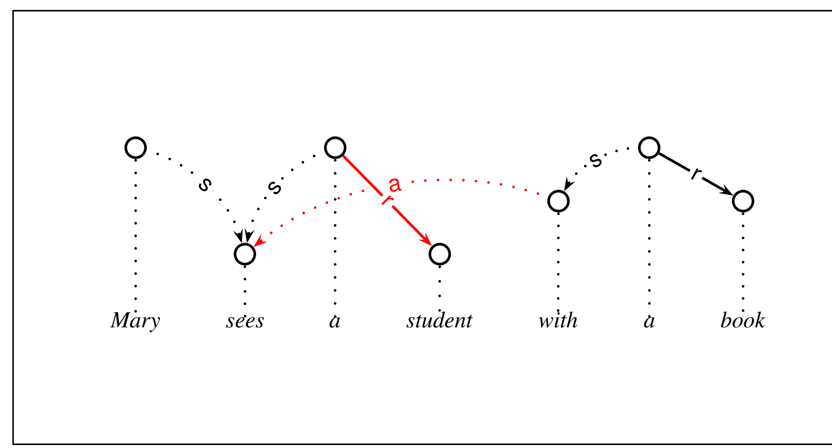


Linear Precedence (LP)



Predicate–Argument (PA)



Scope (SC)

Summary

- XDG can be used to implement a *relational syntax-semantics interface* that supports the *concurrent flow of information*
- supports *underspecification*
- the dimensions can be linked by *multi-dimensional principles* and *mutually constrain each other*
- no dimension is more “basic” than another, each leads a life on its own

Future Work

- find a *uniform representation formalism for principles*
- *generalization of XDG and CLLS* into a single formalism, working title *Graph Configuration Meta Language* (GCML)
- make *XDG efficient on large grammars*
- *import of large grammars* (e.g. XTAG, ERG)
- *induction of large grammars* (e.g. from Penn TB, PDT)