Semantic Analysis and Semantic Roles

Ling 571
Deep Processing Techniques for NLP
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Roadmap

- Semantic Analysis
  - Semantic attachments
    - Extended example
  - Quantifier scope
  - Earley Parsing and Semantics
- Semantic role labeling (SRL):
  - Motivation:
    - Between deep semantics and slot-filling
  - Thematic roles
  - Thematic role resources
    - PropBank, FrameNet
  - Automatic SRL approaches

NP Attachments

- Noun → restaurant $\{\lambda x.Restaurant(x)\}$
- Nom → Noun { Noun.sem }
- Det → Every $\{\lambda P.\lambda Q.\forall x P(x) \Rightarrow Q(x)\}$
- NP → Det Nom { Det.sem(Nom.sem) }

$$\lambda Q.\forall x \, Restaurant(x) \Rightarrow Q(x)$$

Simple VP Representation

- Verb → close $\{\lambda x.\exists e Closed(e) \wedge ClosedThing(e,x)\}$
- VP → Verb { Verb.sem }
- S → NP VP { NP.sem(VP.sem) }

$$\lambda Q.\forall x \text{Re}\,staurant(x) \Rightarrow Q(x)(\lambda y.\exists e Closed(e) \wedge ClosedThing(e,y))$$

$$\forall x \text{Re}\,staurant(x) \Rightarrow \exists e Closed(e) \wedge ClosedThing(e,x)$$

Extending Attachments

- ProperNoun → Maharani
- What should semantics look like in this style?
  - Needs to produce correct form when applied to VP.sem
    - As in "Maharani closed" ➔

$$\exists e Closed(e) \wedge ClosedThing(e, Maharani)$$

- Correct form: λ x.x(Maharani)
  - Applies predicate to Maharani

More Attachments

- Determiner
- Det → a $\{ \quad \lambda P.\lambda Q.\exists x P(x) \wedge Q(x) \quad \}$
- a restaurant $\lambda Q.\exists x \mathrm{Re}\, staurant(x) \wedge Q(x)$

- Transitive verb:
  - VP → Verb NP { Verb.sem(NP.sem) }
  - Verb → opened

$$\lambda w.\lambda z.w(\lambda x.\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,x))$$

Strategy for Semantic Attachments

- General approach:
  - Create complex lambda expressions with lexical items
    - Introduce quantifiers, predicates, terms
  - Percolate up semantics from child if non-branching
  - Apply semantics of one child to other through lambda
    - Combine elements, but don't introduce new

Matthew opened a restaurant

- Proper_Noun → Matthew {λ x.x(Matthew))
- VP → Verb NP {Verb.sem(NP.sem)}

$$\lambda w.\lambda z.w(\lambda x.\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,x))$$

- $(\lambda Q.\exists y \operatorname{Re} staurant(y) \wedge Q(y))$

$$\lambda z.(\lambda Q.\exists y \operatorname{Re} staurant(y) \wedge Q(y)$$

$$(\lambda x.\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,x)))$$

$$\lambda z.\exists y \operatorname{Re} staurant(y) \wedge$$

$$\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,y))$$

Matthew opened a restaurant

- Proper_Noun → Matthew {λ x.x(Matthew)}
- S → NP VP {NP.sem(VP.sem)}
- λ x.x(Matthew)

$$(\lambda z.\exists y \mathrm{Re}\, staurant(y) \wedge$$
$$\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,y))$$

$$(\lambda z.\exists y \mathrm{Re}\, staurant(y) \wedge$$
$$\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,y))(Matthew)$$

Matthew opened a restaurant

$$(\lambda z.\exists y \mathrm{Re}\,staurant(y) \wedge$$
$$\exists e Opened(e) \wedge Opener(e,z) \wedge OpenedThing(e,y))(Matthew)$$

$$\exists y \mathrm{Re}\,staurant(y) \wedge$$
$$\exists e Opened(e) \wedge Opener(e, Matthew) \wedge OpenedThing(e,y)$$

Sample Attachments

Grammar Rule	Semantic Attachment
$S \rightarrow NP\ VP$	$\{NP.sem(VP.sem)\}$
$NP \rightarrow Det\ Nominal$	$\{Det.sem(Nominal.sem)\}$
$NP \rightarrow ProperNoun$	$\{ProperNoun.sem\}$
$Nominal \rightarrow Noun$	$\{Noun.sem\}$
$VP \rightarrow Verb$	$\{Verb.sem\}$
$VP \rightarrow Verb\ NP$	$\{Verb.sem(NP.sem)\}$
$Det \rightarrow every$	$\{\lambda P.\lambda Q.\forall x P(x) \Rightarrow Q(x)\}$
$Det \rightarrow a$	$\{\lambda P.\lambda Q.\exists x P(x) \wedge Q(x)\}$
$Noun \rightarrow restaurant$	$\{\lambda r.Restaurant(r)\}$
$ProperNoun \rightarrow Matthew$	$\{\lambda m.m(Matthew)\}$
$ProperNoun \rightarrow Franco$	$\{\lambda f.f(Franco)\}$
$ProperNoun \rightarrow Frasca$	$\{\lambda f.f(Frasca)\}$
$Verb \rightarrow closed$	$\{\lambda x.\exists e Closed(e) \wedge ClosedThing(e,x)\}$
$Verb \rightarrow opened$	$\{\lambda w.\lambda z.w(\lambda x.\exists e Opened(e) \wedge Opener(e,z)$ $\wedge Opened(e,x))\}$

Semantics Learning

- Zettlemoyer & Collins, 2005, 2007, etc; Mooney 2007
- Given semantic representation and corpus of parsed sentences
  - Learn mapping from sentences to logical form
    - Structured perceptron
    - Applied to ATIS corpus sentences
- Similar approaches to: learning instructions from computer manuals, game play from walkthroughs, robocup/soccer play from commentary

Quantifier Scope

- Ambiguity:
  - *Every restaurant has a menu*

$$\forall x \, Restaurant(x) \Rightarrow \exists y (Menu(y) \wedge (\exists e Having(e) \wedge Haver(e,x) \wedge Had(e,y)))$$

  - Readings:
    - all have a menu;
    - all have same menu
  - Only derived one

$$\exists y Menu(y) \wedge \forall x (Restaurant(x) \Rightarrow \exists e Having(e) \wedge Haver(e,x) \wedge Had(e,y)))$$

  - Potentially O(n!) scopings (n=# quantifiers)

- There are approaches to describe ambiguity efficiently and recover all alternatives.

Earley Parsing with Semantics

- Implement semantic analysis
  - In parallel with syntactic parsing
    - Enabled by compositional approach
- Required modifications
  - Augment grammar rules with semantic field
  - Augment chart states with meaning expression
  - Completer computes semantics
    - Can also fail
      - Blocks semantically invalid parses
    - Can impose extra work

Semantic Analysis

- Applies principle of compositionality
  - Rule-to-rule hypothesis
  - Links semantic attachments to syntactic rules
    - Incrementally ties semantics to parse processing
    - Lambda calculus meaning representations
    - Most complexity pushed into lexical items
    - Non-terminal rules largely lambda applications