Semantic analysis & Lexical Semantic
ICS 482 Natural Language Processing

Lecture 22: Semantic analysis & Lexical Semantic

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NLP Credits and Acknowledgment

These slides were adapted from presentations of the Authors of the book

SPEECH and LANGUAGE PROCESSING:

An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition

and some modifications from presentations found in the WEB by several scholars including the following

NLP Credits and Acknowledgment

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NLP Credits and Acknowledgment

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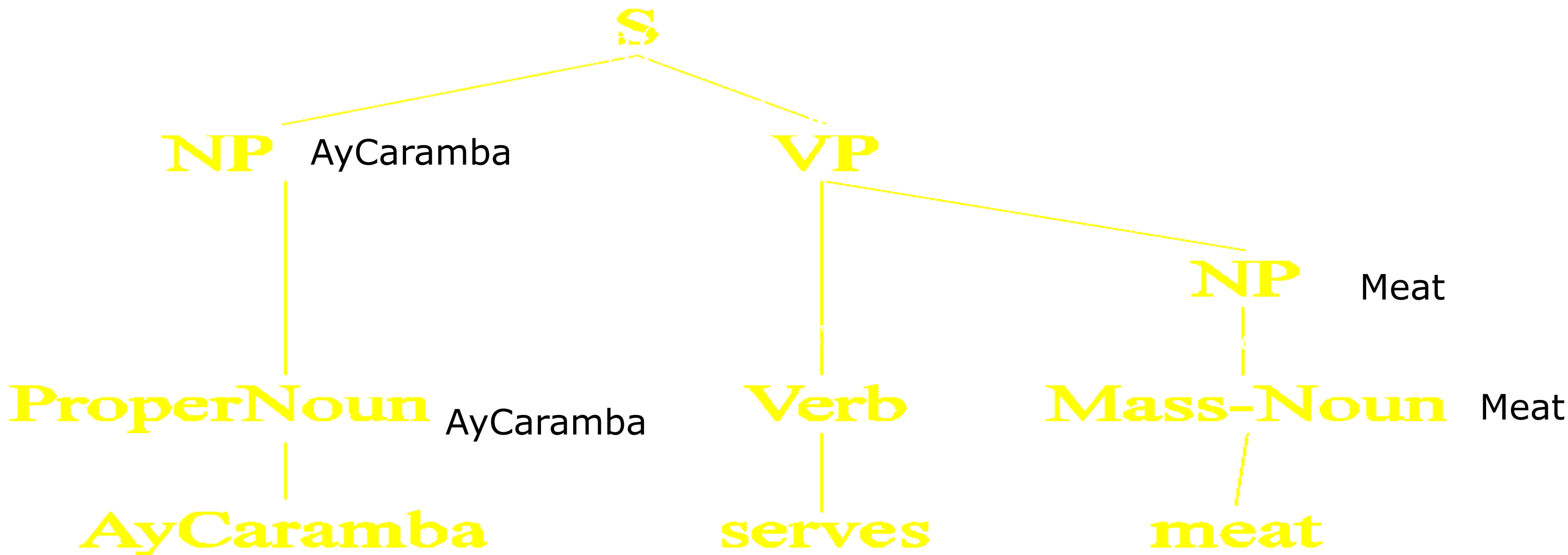
Previous Lectures

- Introduction and Phases of an NLP system
- NLP Applications - Chatting with Alice
- Finite State Automata & Regular Expressions & languages
- Morphology: Inflectional & Derivational
- Parsing and Finite State Transducers, Porter Stemmer
- Statistical NLP – Language Modeling
- N Grams, Smoothing
- Parts of Speech - Arabic Parts of Speech
- Syntax: Context Free Grammar (CFG) & Parsing
- Parsing: Earley's Algorithm
- Probabilistic Parsing
- Probabilistic CYK - Dependency Grammar
- Semantics: Representing meaning - FOPC
- Lexicons and Morphology – invited lecture
- Semantics: Representing meaning
- Semantic Analysis: Syntactic-Driven Semantic Analysis

Today's Lecture

- Semantic Analysis (~ Ch 15)
  - Syntactic-Driven Semantic Analysis
  - Semantic Grammars
- Presentations
  - Evaluation
  - How to give good presentation



- $S \rightarrow NP\ VP$ — {VP.sem(NP.sem)}
- $VP \rightarrow Verb\ NP$ — {Verb.sem(NP.sem)}
- $Verb \rightarrow serves$ — $\lambda x\, \lambda y\ \exists e\ Serving(e) \wedge Server(e, y) \wedge Served(e, x)$
- $NP \rightarrow PropNoun$ — {PropNoun.sem}
- $NP \rightarrow MassNoun$ — {MassNoun.sem}
- PropNoun → *AyCaramba* — {AyCaramba}
- MassNoun → *meat* — {MEAT}

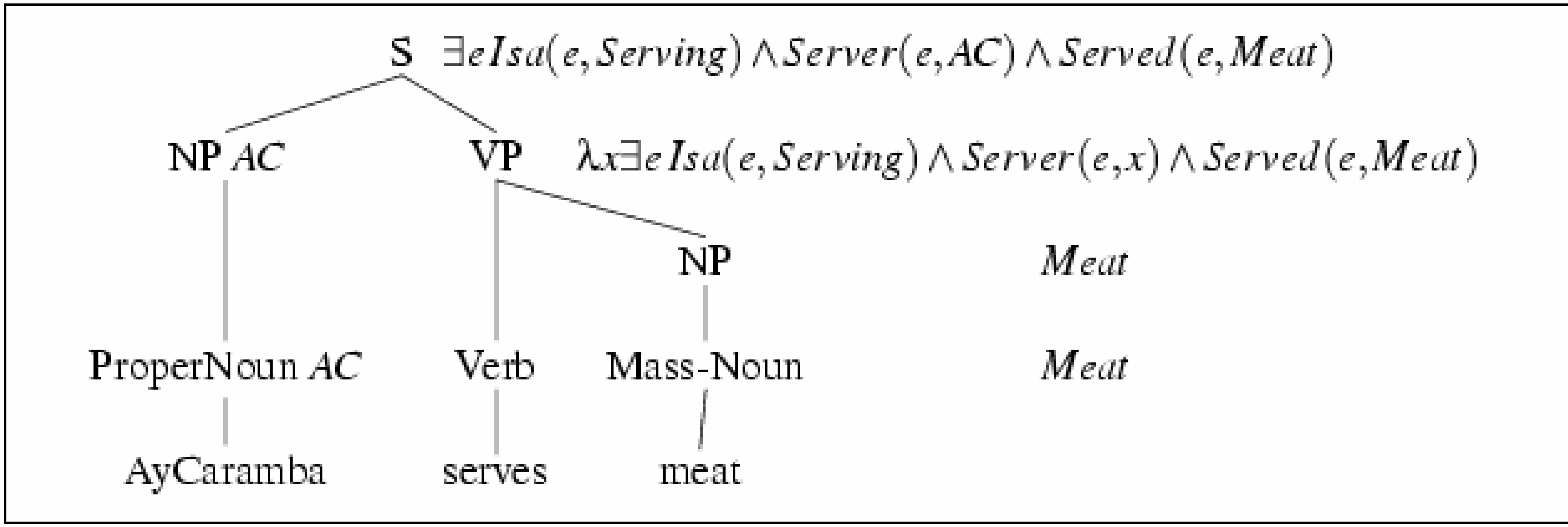
Which FOPC representation is better?

$$\lambda x \lambda y \exists e Serving(e) \wedge Server(e,y) \wedge Served(e,x)$$

$$\lambda x \lambda y \exists e Isa(e, Serving) \wedge Server(e,y) \wedge Served(e,x)$$

Possible pop-quiz: Redo previous example using second representation

Syntax-Driven Semantic Analysis
Semantic Augmentation to CFG Rules



- Revise *Verb* attachment

$$Verb \rightarrow serves\ \{\lambda x\, \lambda y\, \exists e\ Isa(e, Serving) \wedge Server(e, y) \wedge Served(e, x)\}$$

Predicate-Argument Semantics

- The functions/operations permitted in the semantic rules fall into two classes
  - Pass the semantics of a daughter up unchanged to the mother
  - Apply (as a function) the semantics of one of the daughters of a node to the semantics of the other daughters

Predicate-Argument Semantics

- S → NP VP
- VP → Verb NP

- {VP.sem (NP.sem)}
- {Verb.sem (NP.sem)

- in each rule there’s a daughter whose semantics is a function and one that isn’t.

Integration with a Parser

- Assume you're using a dynamic-programming style parser (Earley or CYK).
- As constituents are completed and entered into the table, we compute their semantics.
  - If they're complete, we have their parts.
  - If we have their parts we have the semantics for the parts…
  - Therefore we can compute the semantics of the newly completed constituent.

Mismatches

- There are unfortunately some annoying mismatches between the syntax of FOPC and the syntax provided by our grammars…
- So we'll accept that we can't always directly create valid logical forms in a strictly compositional way

Quantified Phrases

- Consider

  A restaurant serves meat.

- Assume that A restaurant looks like

$$\exists x\ Isa(x, Restaurant)$$

- If we do the normal lambda thing we get

$$\exists e Serving(e) \wedge Server(e, \exists x Isa(x, Restaurant)) \wedge Served(e, Meat)$$

Semantic Augmentation to CFG Rules

- A restaurant serves meat.
  - Subject

    $\exists x\ Isa(x, Restaurant)$
  - Embed in the *Server* predicate:

$$\exists e\ Isa(e, Serving) \wedge Server(e, \exists x\ \boldsymbol{Isa(x, Restaurant)}) \wedge Served(e, Meat)$$

Not a valid FOPC

Semantic Augmentation to CFG Rules

- Solve this problem by introducing the notion of a **complex-term**.
  - A complex term: $< \textit{Quantifier variable body} >$

$$\exists e\ Isa(e, Serving) \wedge Server(e, \boldsymbol{<\exists x\ Isa(x, Restaurant>})) \wedge Served(e, Meat)$$

  - Rewriting a predicate using a complex-term

$$P(< \textit{Quantifier variable body} >) \Rightarrow$$
$$\textit{Quantifier variable body Connective } P(\textit{variable})$$

$$Server(e, < \exists x\ Isa(x, Restaurant>) \Rightarrow \exists x\ Isa(x, Restaurant) \wedge Server(e, x)$$

Complex Terms

- Allow the compositional system to pass around representations like the following as objects with parts:

$$< \exists x \; Isa(x, \text{Restaurant}) >$$

`Complex-Term : <Quantifier var body>`

Example

- Our restaurant example winds up looking like

$$\exists e Serving(e) \wedge Server(e, < \exists x Isa(x, Restaurant) >) \wedge Served(e, Meat)$$

Conversion

- So… complex terms wind up being embedded inside predicates. So pull them out and redistribute the parts in the right way…

P(<quantifier, var, body>)

turns into

Quantifier var body connective P(var)

Example

$$Server(e, <\exists x\ Isa(x, \text{Restaurant})>)$$

$$\Rightarrow$$

$$\exists x\ Isa(x, \text{Restaurant}) \wedge Server(e, x)$$

Quantifiers and Connectives

- If the quantifier is an existential, then the connective is an ^ (and)

- If the quantifier is a universal, then the connective is an => (implies)

Multiple Complex Terms

- Note that the conversion technique pulls the quantifiers out to the front of the logical form…
- That leads to ambiguity if there's more than one complex term in a sentence.

Multiple Complex Terms

- Every restaurant has a menu.

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

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

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

Try to simplify this multiple complex term

Multiple Complex Terms

- The problem of ambiguous **quantifier scoping** — a single logical formula with two complex-terms give rise to two distinct and incompatible FOPC representations.

Ambiguity

- The number of possible interpretations goes up exponentially with the number of complex terms in the sentence
- The best we can do is to come up with weak methods to prefer one interpretation over another

Attachments for a Fragment of English Sentences

- Flight 487 serves lunch.

  $S \rightarrow NP\ VP\ \{DCL(VP.sem(NP.sem))\}$

- Serve lunch.

  $S \rightarrow VP\ \{IMP(VP.sem(DummyYou))$

  $IMP(\exists e Serving(e) \wedge Server(e, DummyYou) \wedge Served(e, Lunch)$

  Imperatives can be viewed as a kind of **speech act**.

For Reference

- Does Flight 207 serve lunch?

  $S \rightarrow Aux\ NP\ VP\ \{YNQ(VP.sem(NP.sem))\}$

  $YNQ(\exists e Serving(e) \wedge Server(e, Flt207) \wedge Served(e, Lunch)$

- Which flights serve lunch?

  $S \rightarrow WhWord\ NP\ VP\ \{WHQ(NP.sem.var, VP.sem(NP.sem))\}$

  $WHQ(x, \exists e, x\ Isa(e, Serving) \wedge Server(e, x) \wedge Served(e, Lunch) \wedge Isa(x, Flight))$

Attachments for a Fragment of English Sentences

- How can I go from Minneapolis to Long Beach?

$$S \rightarrow WhWord\ Aux\ NP\ VP\ \{WHQ(WhWord.sem,\ VP.sem(NP.sem))\}$$

$$WHQ(How, \exists e\ Isa(e, Going) \wedge Goer(e, User) \wedge Origin(e, Minn) \wedge Destination(e, LongBeach))$$

Attachments for a Fragment of English
NPs: Compound Nominals

- The meaning representations for NPs can be either normal FOPC terms or complex-terms.
- Flight schedule
- Summer flight schedule

$$Nominal \rightarrow Noun$$

$$Nominal \rightarrow Nominal\ Noun\ \{\lambda x\ Nominal.sem(x) \wedge NN(Noun.sem, x)\}$$

$$\lambda x\ Isa(x, Schedule) \wedge NN(x, Flight)$$

$$\lambda x\ Isa(x, Schedule) \wedge NN(x, Flight) \wedge NN(x, Summer$$

Attachments for a Fragment of English
NP: Genitive NPs

- (Ex.) Atlanta's airport
- (Ex.) Maharani's menu

$$NP \rightarrow ComplexDet\ Nominal$$

$$\{<\exists x Nominal.sem(x) \wedge GN(x, ComplexDet.sem)>\}$$

$$ComplexDet \rightarrow NP's\ \{NP.sem\}$$

$$<\exists x\ Isa(x, Airport) \wedge GN(x, Atlanta)>$$

Attachments for a Fragment of English
Adjective Phrases

- I don't mind a cheap restaurant.
- This restaurant is cheap.
- For pre-nominal case, an obvious and *often incorrect* proposal is:

$Nominal \rightarrow Adj\ Nominal$

$\{\lambda x\ Nominal.sem(x) \wedge Isa(x, Adj.sem)\}$

$Adj \rightarrow cheap\ \{Cheap\}$

$\lambda x\ Isa(x, Restaurant) \wedge Isa(x, Cheap)$ **intersective semantics**

- ***Wrong***
  - $small\ elephant \Rightarrow \lambda x\ Isa(x, Elephant) \wedge Isa(x, Small)$
  - $former\ friend \Rightarrow \lambda x\ Isa(x, Friend) \wedge Isa(x, Former)$
  - $fake\ gun \Rightarrow \lambda x\ Isa(x, Gun) \wedge Isa(x, Fake)$

} ***Incorrect interactions***

Attachments for a Fragment of English
Adjective Phrases

- The best approach is to simply note the status of a special kind of modification relation and
  - Assume that some further procedure with access to additional relevant knowledge can replace this vague relation with an appropriate representation.

$$Nominal \rightarrow Adj\ Nominal$$

$$\{\lambda x\ Nominal.sem(x) \wedge AM(x,\ Adj.sem)\}$$

$$Adj \rightarrow cheap\ \{Cheap\}$$

$$\lambda x\ Isa(x,\ Restaurant) \wedge AM(x,\ Cheap)$$

Attachments for a Fragment of English
VPs: Infinite VPs

- In general, the λ-expression attached to the verb is simply applied to the semantic attachments of the verb's arguments.
- However, some special cases, for example, infinite VP
- (15.13) I told Harry to go to Maharani.
  - The meaning representation could be:

$$\exists e, f, x\ Isa(e, Telling) \wedge Isa(f, Going) \wedge Teller(e, Speaker) \wedge Tellee(e, Harry) \wedge ToldThing(e, f) \wedge Goer(f, Harry) \wedge Destination(f, x)$$

  - Two things to note:
    - It consists of two events, and
    - One of the participants, *Harry*, plays a role in both of the two events.

Attachments for a Fragment of English
VPs: Infinite VPs

- A way to represent the semantic attachment of the verb, *tell*

  $\lambda x, y \lambda z \exists e\ Isa(e, Telling) \wedge Teller(e, z) \wedge Tell(e, x) \wedge ToldThing(e, y)$

  - Providing three semantic roles:
    - a person doing the telling,
    - a recipient of the telling, and
    - the proposition being conveyed
  - **Problem:**
    - Harry is not available when the *Going* event is created within the infinite verb phrase.

Attachments for a Fragment of English
VPs: Infinite VPs

- Solution:

$$VP \rightarrow Verb \;\; NP \;\; VPto \quad \{Verb.sem(NP.sem,\; VPto.sem)\}$$

$$VPto \rightarrow to \; VP \; Verb \;\; NP \; \{VP.sem\}$$

$$Verb \rightarrow tell \quad \{\lambda x, y \, \lambda z \; \exists e, y.variable \; Isa(e, Telling) \wedge Teller(e, z) \wedge Tellee(e,x) \wedge ToldThing(e, y.variable) \wedge y(x)\}$$

For Reference

  - The λ-variable *x* plays the role of the *Tellee* of the telling and the argument to the semantics of the infinitive, which is now contained as a λ-expression in the variable *y*.
  - The expression *y*(*x*) represents a λ-reduction that inserts *Harry* into the *Going* event as the *Goer.*
  - The notation *y.variable* is analogous to the notation used for complex-terms variables, and gives us access to the event variable representing *Going* event within the infinitive's meaning representation.

Attachments for a Fragment of English

Prepositional Phrases

- At an abstract level, PPs serve two functions:
  - They assert binary relations between their heads and the constituents to which they attached, and
  - They signal arguments to constituents that have an argument structure.
- We will consider three places in the grammar where PP serve these roles:
  - Modifiers of NPs
  - Modifiers of VPs, and
  - Arguments to VPs

Attachments for a Fragment of English
PP: Nominal Modifier

- (15.14) A restaurant on Pearl

$$\exists x\ Isa(x, Restaurant) \wedge On(x, Pearl)$$

$$NP \rightarrow Det\ Nominal$$

$$Nominal \rightarrow Nominal\ PP \quad \{\lambda z\ Nominal.sem(z) \wedge PP.sem(z)\}$$

$$PP \rightarrow P\ NP \quad \{P.sem(NP.sem)\}$$

$$P \rightarrow on \quad \{\lambda y\, \lambda x\ On(x,y)\}$$

Attachments for a Fragment of English
PP: VP Modifier

- (Ex.) ate dinner in a hurry

  $VP \rightarrow VP\ PP$

  - The meaning representation of *ate dinner*

    $\lambda x \exists e\ Isa(e, Eating) \wedge Eater(e, x) \wedge Eaten(e, Dinner)$
  - The representation of the PP

    $\lambda x\ In(x, <\exists h\ Hurry(h)>)$
  - The correct representation of the modified VP should contain the conjunction of the two
    - With the *Eating* event variable filling the first argument slot of the *In* expression.

    $VP \rightarrow VP\ PP\ \{\lambda y\ VP.sem(y) \wedge PP.sem(VP.sem.variable)\}$
  - The result of application

    $\lambda y \exists e\ Isa(e, Eating) \wedge Eater(e, y) \wedge Eaten(e, Dinner) \wedge In(e, <\exists h\ Hurry(h)>)$

Non-Compositionality

- Unfortunately, there are lots of examples where the meaning (loosely defined) can’t be derived from the meanings of the parts
  - Idioms الأمثال
  - Jokes الدعابة
  - Irony التظاهر بالجهل
  - Sarcasm السخرية
  - Metaphor المجاز أو الاستعارة
  - Metonymy الكناية
  - indirect requests الطلب غير المباشر
- Some Examples in Arabic !!

English Idioms

- Kick the bucket, buy the farm, bite the bullet, run the show, bury the hatchet, etc…
- Lots of these… constructions where the meaning of the whole is either
  - Totally unrelated to the meanings of the parts (kick the bucket)
  - Related in some opaque way (run the show)
  - Kick the bucket: To die
  - buy the farm: to be killed
  - bite the bullet: get serious and do what needs to be done even though you don't want to do it
  - run the show: manage the project
  - bury the hatchet: stop arguing or fighting

Problems with Syntactic-Driven Semantics

- Syntactic structures often don't fit semantic structures very well
  - Important semantic elements often distributed very differently in trees for sentences that mean 'the same'

  I like soup. Soup is what I like.

  - Parse trees contain many structural elements not clearly important to making semantic distinctions
  - Syntax driven semantic representations are sometimes odd

Alternatives?

- Semantic Grammars
- Information Extraction Techniques
- Next time

Student Presentation - Start next time

- Tuesday, May 8
  - Saleh Al-Zaid - Language Model Based Arabic Word Segmentation
- Sunday, May 13
  - Al-Elaiwi Moh'd - Diacritization: A Challenge to Arabic Treebank Annotation and Parsing
  - Naif Al-Abdulhay - The Challenge Of Arabic For NLP/MT
  - Abdul Rahman Al Khaldi - Statistical Transliteration for English-Arabic Cross

Student Presentation

- Tuesday, May 15
  - Turki Bakodah - Building A Modern Standard Arabic Corpus
  - Hassan S. Al-Ayesh - Stemming to improve translation lexicon creation form bitexts
  - Saleh Y. Al-Hudail - A Hidden Markov Model –Based POS Tagger for Arabic

Student Presentation

- Sunday May 20
  - Abbas Al-Julaih - An Ambiguity-Controlled Morphological Analyzer for Modern Standard Arabic Modeling
  - AbdiRahman Daoud - Online Arabic Handwriting Recognition Using HMM
  - Shaker Al-Anazi - How Do Search Engines Handle Arabic Queries?
- Tuesday, May 22
  - Hussain AL-Ibrahem - Arabic Tokenization, Part-of-Speech Tagging
  - Ahmed Bukhamsin - Hybrid Method for Tagging Arabic Text
  - Al-Ansari, Naser - Light Stemming for Arabic Information Retrieval

Student Presentation Evaluation

- Attendance
- Student evaluation is a must (including Youself)
- On time – no make up – 10%
- Fill after attending the presentation
- Honestly evaluate the presentation

Student Presentation Evaluation

- Improve some needed skills in real life work?
- Helps the instructor
- Fill a grade out of 10 for each item
- Do not fill unattended presentation
- Do evaluate your presentation
- Partial grades to be deducted for unfilled evaluation

Student Presentation Evaluation

Items – Each out of 10

- Introduction
- Clarity
- Knowledge Depth
- Content
- Delivery
- Preparation
- Organization
- Language Usage
- Result & Conclusion
- Question & Answer
- Over all Evaluation

22-2 How To Give Good Presentation

Thank you

- السلام عليكم ورحمة الله