Representing Meaning Part 2
ICS 482 Natural Language Processing

Lecture 18: Representing Meaning Part 2

Husni Al-Muhtaseb

بسم الله الرحمن الرحيم

ICS 482 Natural Language Processing

Lecture 18: Representing Meaning Part 2

Husni Al-Muhtaseb

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

If your name is missing please contact me
muhtaseb
At
Kfupm.
Edu.
sa

NLP Credits and Acknowledgment

Husni Al-Muhtaseb
James Martin
Jim Martin
Dan Jurafsky
Sandiway Fong
Song young in
Paula Matuszek
Mary-Angela Papalaskari
Dick Crouch
Tracy Kin
L. Venkata Subramaniam
Martin Volk
Bruce R. Maxim
Jan Hajič
Srinath Srinivasa
Simeon Ntafos
Paolo Pirjanian
Ricardo Vilalta
Tom Lenaerts

Heshaam Feili
Björn Gambäck
Christian Korthals
Thomas G. Dietterich
Devika Subramanian
Duminda Wijesekera
Lee McCluskey
David J. Kriegman
Kathleen McKeown
Michael J. Ciaraldi
David Finkel
Min-Yen Kan
Andreas Geyer-Schulz
Franz J. Kurfess
Tim Finin
Nadjet Bouayad
Kathy McCoy
Hans Uszkoreit
Azadeh Maghsoodi

Khurshid Ahmad
Staffan Larsson
Robert Wilensky
Feiyu Xu
Jakub Piskorski
Rohini Srihari
Mark Sanderson
Andrew Elks
Marc Davis
Ray Larson
Jimmy Lin
Marti Hearst
Andrew McCallum
Nick Kushmerick
Mark Craven
Chia-Hui Chang
Diana Maynard
James Allan

Martha Palmer
julia hirschberg
Elaine Rich
Christof Monz
Bonnie J. Dorr
Nizar Habash
Massimo Poesio
David Goss-Grubbs
Thomas K Harris
John Hutchins
Alexandros Potamianos
Mike Rosner
Latifa Al-Sulaiti
Giorgio Satta
Jerry R. Hobbs
Christopher Manning
Hinrich Schütze
Alexander Gelbukh
Gina-Anne Levow
Guitao Gao
Qing Ma
Zeynep Altan

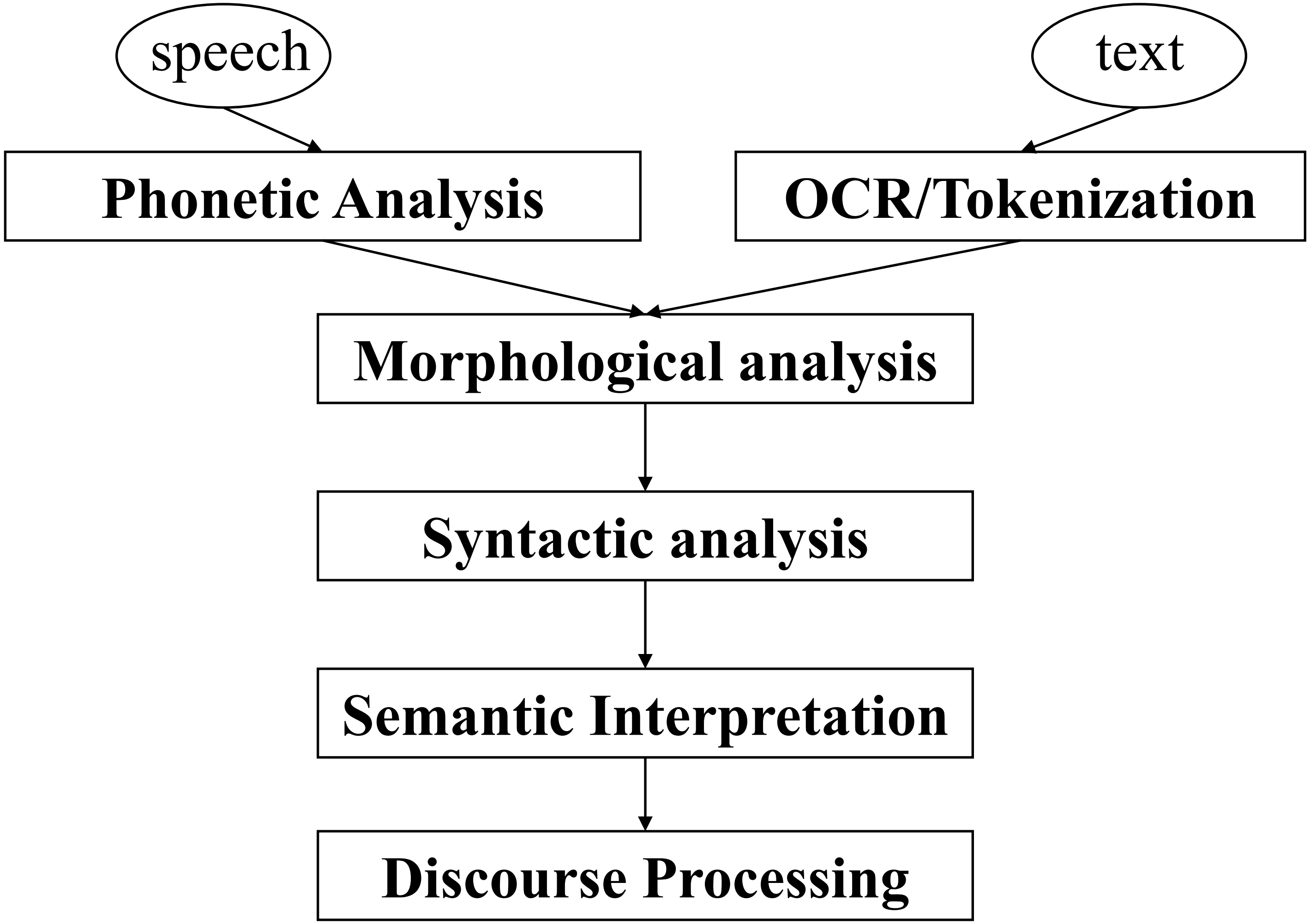
Previous Lectures

- 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 (Cocke-Younger-Kasami)
- Dependency Grammar
- Semantics: Representing meaning

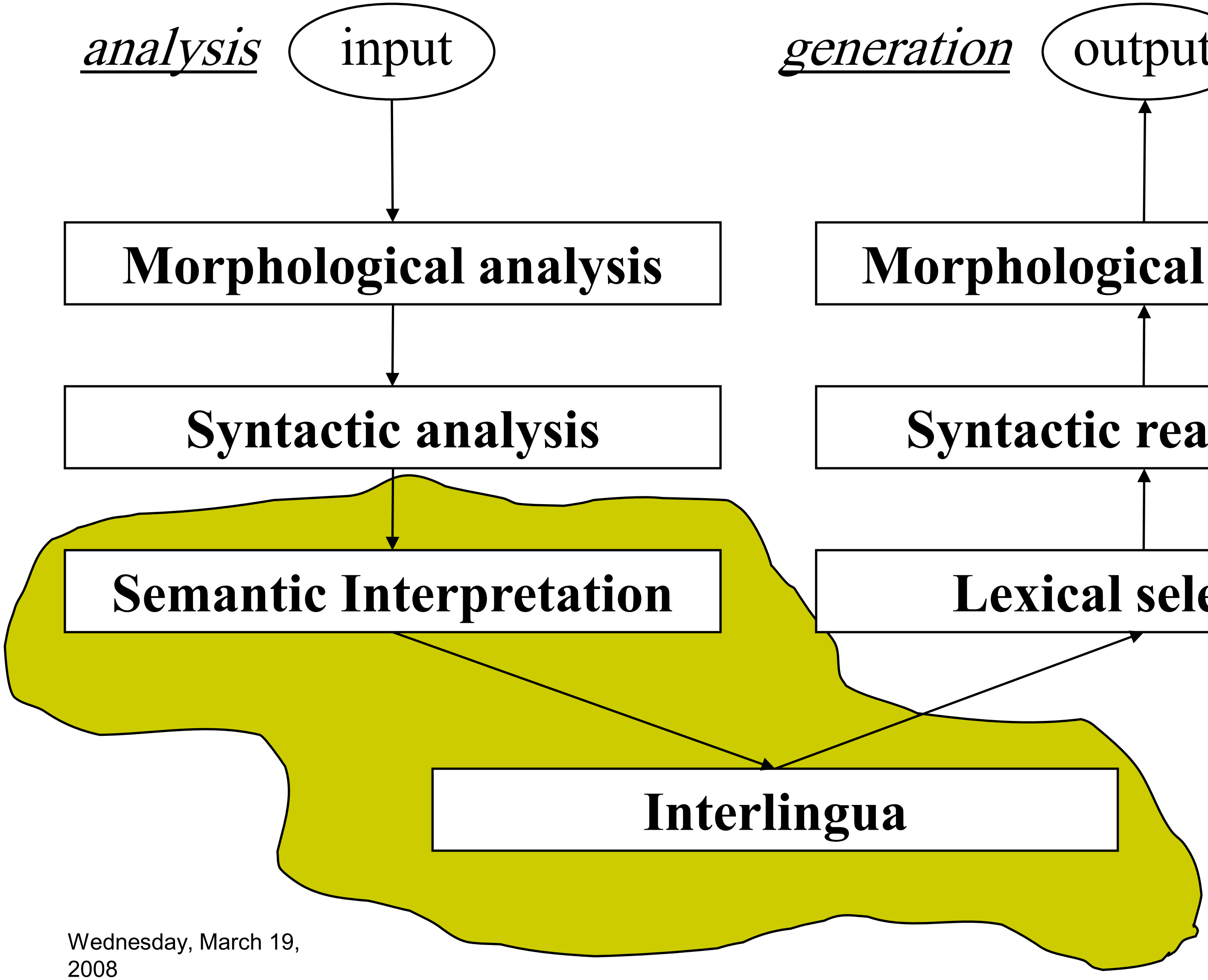
Today's Lecture

- Semantics: Representing meaning
  - First Order Predicate Calculus (FOPC) (Continue with Chapter 14)

NLP Pipeline



Machine Translation



Requirements meaning representations must fulfill? (Last thing discussed)

- Verifiability
- Ambiguity
- Canonical Form
- Inference
- Expressiveness

Meaning Structure of Language

- Various ways by which human language conveys meaning
  - Form-meaning associations
  - Word-order regularities
  - Tense systems
  - Conjunctions and quantifiers
  - **Predicate-argument structure** (today's topic)

Later

Predicate-Argument Structure

- Represents concepts and relationships among them
  - Nouns as concepts or arguments (red (**ball**))
  - Adjectives, adverbs, verbs as predicates (**red** (ball))
- Subcategorization (or, argument) frames specify number, position, and syntactic category of arguments
  - *I want Italian food*
    - NP *want* NP
  - *I want to spend less than five dollars*
    - NP *want* Inf-VP
  - *I want it to be close by here*
    - NP *want* NP Inf-VP

What Do Syntactic Frames Say?

NP want NP

- Predicate *want* has 2 arguments, both NPs
  - 1st argument is pre-verbal, plays the role of subject
  - 2nd argument is post-verbal, plays the role of object

↓

Extend semantic frames with semantic roles and semantic restrictions on the roles

Semantic (Thematic) Roles

- Subcategorization frames link arguments in surface structure with their semantic roles
  - Agent: Sami hit Asem. Asem was hit by Sami.
  - Patient: Sami hit Asem. Asem was hit by Sami .
- **Selectional Restrictions:** constraints on the ***types*** of arguments verbs take
  - *George assassinated (اغتال) the senator.*
  - **The spider assassinated the fly.* (incorrect)
  - *assassinate: intentional (political?) killing*

Representational Schemes

- Make use of First Order Predicate Calculus (FOPC) as our representational framework
  - Not because its perfect
  - All the alternatives turn out to be either too limiting or
  - They turn out to be notational variants

FOPC

- FOPC: provides a sound computational basis for the verifiability, inference, and expressiveness requirements
  - The analysis of truth conditions
    - Allows us to answer yes/no questions
  - Supports the use of variables
    - Allows us to answer questions through the use of variable binding
  - Supports inference
    - Allows us to answer questions that go beyond what we know explicitly

Predicate Calculus

- Calculus
  - Not directly related to the differential or integral calculus we already know.

What is “Calculus”?

- Calculus (from www.dictionary.com):
  1. Pathology. An abnormal concretion in the body, usually formed of mineral salts and found in the gall bladder, kidney, or urinary bladder, for example.
  2. Dentistry. Tartar.

What is “Calculus”?

- Calculus (from www.dictionary.com):
  3. Abbr. calc. Mathematics
     a. The branch of mathematics that deals with limits and the differentiation and integration of functions of one or more variables. [What we usually think of.]
     b. A method of analysis or calculation using a special symbolic notation. [What we will talk about today.]
     c. The combined mathematics of differential calculus and integral calculus. [What we usually think of.]
  4. A system or method of calculation: “ [a] dazzling grasp of the nation's Byzantine budget calculus”

Predicate Calculus

- We have “Terms”, which can be either:
  - Constants
  - Variable symbols
  - Compound terms (function symbol + arguments), e.g.:
    - age (ahmad)
    - distance (point1, X)
- “Atomic Propositions” express relationships between objects.
  - Predicate symbols + arguments, e.g.:
    - human (ahmad)
    - likes (man, game(football))

Predicate Calculus: First- and Second-Order

- First-order predicate calculus only allows simple variables. Second-order predicate calculus allows variables that may themselves be predicates. The language Prolog is, for the most part, a first-order predicate calculus system.

FOPC Syntax

- *Formula* $\rightarrow$ *AtomicFormula*
  $|$ *Formula Connective Formula*
  $|$ *Quantifier Variable … Formula*
  $|$ $\neg$ *Formula* $|$ *(Formula)*
- *AtomicFormula* $\rightarrow$ *Predicate (Term…)*
- *Term* $\rightarrow$ *Function (Term…)* $|$ *Constant* $|$ *Variable*
- *Connective* $\rightarrow \wedge \mid \vee \mid \Rightarrow$
- *Quantifier* $\rightarrow \forall \mid \exists$
- *Constant* $\rightarrow$ *A* $|$ *VegetarianFood* $|$ الكتاب
- *Variable* $\rightarrow x \mid y \mid \ldots$
- *Predicate* $\rightarrow$ *Serves* $|$ *Near* $|$ …
- *Function* $\rightarrow$ *LocationOf* $|$ *CuisineOf* $|$ …

First-order Logic

- Objects: things with individual identities and properties
  - e.g., people, houses, computers, numbers, Ali Jan, color
- Properties: used to distinguish an object from other objects
  - e.g., tall, western style, multimedia, prime, English, red
- Relations: exist and hold among the objects
  - e.g., father of, bigger than, made after, equal, student of
- Functions: relations in which there is only one “value” for a given “input”
  - e.g., brother of, increment of, forward, one more than

First-order Logic

- Almost any fact can be thought of as referring to objects and properties or relations. Examples:
  - <u>One plus two equals three.</u>
    - Objects: one, two, three, one plus two
    - Relations: equals
    - Function: plus
  - <u>Classes near the gate are hot.</u>
    - Objects: classes, gate
    - Property: hot
    - Relation: near

Syntax of FOL: basic element

- Constant symbols: refer to the same object in the same interpretation
  - e.g. Ahmad Asem, 4, A, B, …
- Predicate symbols: refer to a particular relation in the model
  - e.g., brother, >,
- Function symbols: refer to particular objects without using their names
  - Some relations are functional, that is, any given object is related to exactly one other object by the relation. (one-one relation)
  - e.g., Cosine, fatherOf

Syntax of FOL: basic element

- Variables: substitute the name of an object
  - e.g., x, y, a, b
  - $\forall x, cat(x) \Rightarrow mammal(x)$
    - if x is a cat then x is a mammal
- Logic connectives:
  - $\neg$ (not), $\wedge$ (and), $\vee$ (or), $\Rightarrow$ (implies)
- Quantifiers:
  - $\forall$ (universal quantification symbol)
    - $\forall x$, for any x
  - $\exists$ (existential quantification symbol)
    - $\exists x$, there is an x

FOPC Syntax

- **Terms:** constants, functions, variables
  - **Constants**: objects in the world, e.g. *Maharani*
  - **Functions:** concepts, e.g. *LocationOf(Maharani)*
  - **Variables:** *x*, e.g. *LocationOf(x)*
- **Predicates:** symbols that refer to relations that hold among objects in some domain or properties

  Serves(Maharani, VegetarianFood)

  Restaurant(Maharani)

FOPC Syntax

- **Logical connectives** permit compositionality of meaning: $\neg \wedge \vee \Rightarrow$

I only have five dollars and I don't have a lot of time

Have(Speaker, FiveDoallars) $\wedge \neg$ *Have(Speaker, LotofTime)*

FOPC Semantics

- Sentences in FOPC can be assigned truth values, T or F, based on whether the propositions they represent are T or F in the world knowledge
  - Atomic formulae are T or F based on their presence or absence in a Knowledge Base (KB) - Closed World Assumption?
  - Composed meanings are inferred from KB and meaning of logical connectives

Variables and Quantifiers

Existential quantification (∃): "There exists"

a restaurant that serves Mexican food near ICSI

$\exists\, x Restaurant(x) \wedge Serves(x, MexicanFood)$

$\wedge\, Near(LocationOf(x), LocationOf(ICSI))$

for this logical formula to be true there must be at least one object such that if we were substitute it for the variable *x*, the resulting formula is true

Break: What is what?

- Identify:
  - *Connective:* $\wedge$
  - *Quantifier:* $\exists$
  - *Constant:* *MexicanFood* *ICSI*
  - *Variable:* x
  - *Predicate:* *Restaurant* *Serves* *Near*
  - *Function:* *LocationOf*
  - *AtomicFormula:* *Restaurant*
  - *Formula:* $\exists\, x Restaurant(x) \wedge Serves(x, MexicanFood) \wedge Near(LocationOf(x), LocationOf(ICSI))$
  - *Term:* x *ICSI* *LocationOf*

$$\exists\, x Restaurant(x) \wedge Serves(x, MexicanFood) \wedge Near(LocationOf(x), LocationOf(ICSI))$$

Variables and Quantifiers

Universal quantification ($\forall$): "for all"

All vegetarian restaurants serve vegetarian food

$$\forall x \, VegetarianRestaurant(x) \Rightarrow Serves(x, VegetarianFood)$$

for this logical formula to be true the substitution of any object in the knowledge base for the universally quantifier variable should result in a true formula

Inference

- Modus ponens: (if-then reasoning)

$$\frac{\alpha \qquad \alpha \Rightarrow \beta}{\beta}$$

$P \Rightarrow Q$ is equivalent to $\neg P \vee Q$

α: antecedent of $\alpha \Rightarrow \beta$

β: consequent of $\alpha \Rightarrow \beta$

- Is implemented
  - Forward chaining
    - If α is true and $\alpha \Rightarrow \beta$, then β is true
  - Backward chaining
    - If $\alpha \Rightarrow \beta$ is true, then β is true if α is true. $\rightarrow$ **Prolog**
    - Is different from reasoning backwards from known consequents to unknown antecedents
      - $\alpha \Rightarrow \beta$ and β, then α (abduction, plausible reasoning)
      - Abduction: plausible reasoning from known consequents to unknown antecedents

Inference

- Modus ponens: (if-then reasoning)

$$\frac{\begin{array}{l}\alpha \\ \alpha \Rightarrow \beta\end{array}}{\beta}$$

- Inference from consequents to antecedents
  - α explains β
- Diagnostic reasoning
  - (α is a disease/ cause, β is a symptom)

Inference

- Example

$$VegetarianRestaurant(Rudys)$$

$$\frac{\forall x\ VegetarianRestaurant(x) \Rightarrow Serve(x, VegetarianFood)}{Serve(Rudys, VegetarianFood)}$$

a new fact

Truth Tables for Connectives

P	Q	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Rightarrow Q$
False	*False*	*True*	*False*	*False*	*True*
False	*True*	*True*	*False*	*True*	*True*
True	*False*	*False*	*False*	*True*	*False*
True	*True*	*False*	*True*	*True*	*True*

Administration

- Reminder: Quiz 3
  - Tuesday: 24th April 2007
  - Chapters 10 and 12
  - Chapter 14 is not included in this quiz
  - Previous quiz will be at WebCt
- Presentations
  - Watch the calendar of the course website
  - Only 3 Students per lecture – First-in-basis
  - 25 minutes including the questions for each

Thank you

- السلام عليكم ورحمة الله