Representing Meaning Part 4 & Semantic Analysis

ICS 482 Natural Language Processing

Lecture 21: Representing Meaning Part 4 & Semantic Analysis

Husni Al-Muhtaseb

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NLP Credits and Acknowledgment

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

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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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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 - Dependency Grammar
- Semantics: Representing meaning
- Semantics: FOPC
- Lexicons and Morphology – invited lecture
- Semantics: Representing meaning

Today's Lecture

- Administration
  - Presentations Schedule
  - Teams for project (2 each)
  - Projects
- Lecture
  - Representing Meaning Part 4
  - Semantic Analysis

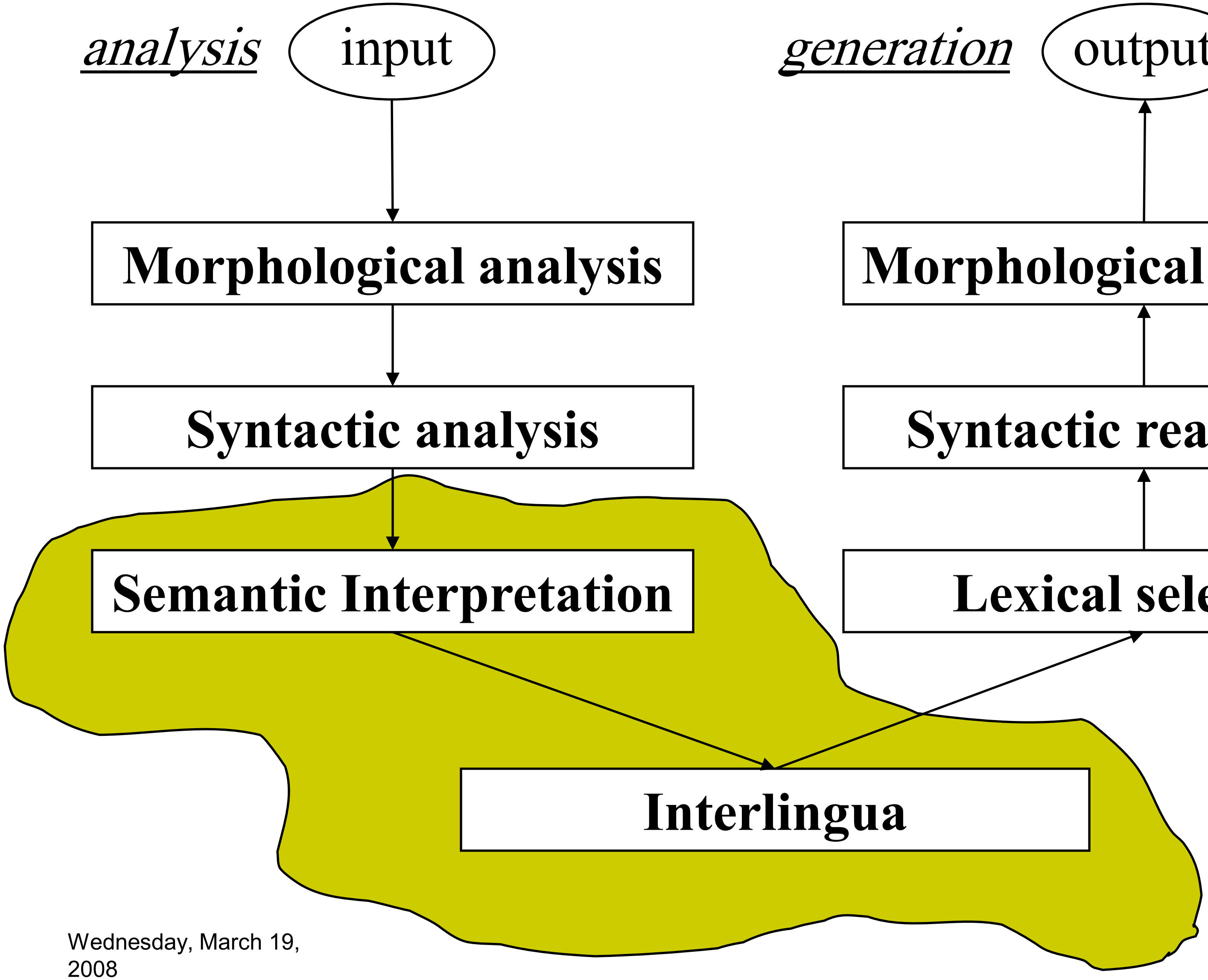
Presentations Schedule

- Presentations at class time
- 13th, 15th, 20th, and 22nd May
- visit the calendar section of this website
- Go to the month of May
- choose one slot in one of the assigned days for presentations
- Add a public entry in the most suitable slot for you
- Max 3 students per slot
- Presentation time: 25 minutes
  - 20 for presentation
  - 5 for discussions
- Put the title of your topic in the entry you are adding

Team

- 2-3 Members (alone)
  - Team Name (Your own)
  - Team logo (Your design idea)
  - By next class
- How to choose Team members
  - Similar goal
  - Easiness of communications
  - Consistency, harmony, and relaxation
  - ??
- WebCt Discussion list – Team Selection
- Project Ideas?

Machine Translation



Representation of Categories

- Categories are sets of objects or relations where all members share a set of features
- Method 1:
  - Create a unary predicate for each category
    - *VegetarianRestaurant(Maharani)*
  - Problem: Unable to talk about *VegetarianRestaurant*
    - Not a valid FOPC formula:
      - *MostPopular(Maharani, VegetarianRestaurant)*

Representation of Categories

- Method 2:
  - Reification اعتبره شيئا ماديا: Represent all concepts that we want to make statements about as full-fledged objects
  - *isa(Maharani, VegetarianRestaurant)*
  - *ako(VegetarianRestaurant, Restaurant)*
    (a kind of)

  - Reification: To regard or treat (an abstraction) as if it had concrete or material existence.

    www.dictionary.com

Representation of Events

- Not always single predicate
  - *I ate*
  - *I ate a turkey sandwich*
  - *I ate a turkey sandwich at my desk*
  - *I ate at my desk*
  - *I ate lunch*
  - *I ate a turkey sandwich for lunch*
  - *I ate a turkey sandwich for lunch at my desk*

Representation of Events

- Method 1:
  - –Create as many *different* eating predicates as are needed to handle all of the ways that eat behaves
  - *Eating1(Speaker)*
  - *Eating2(Speaker, TurkeySandwich)*
  - *Eating3(Speaker, TurkeySandwich, Desk)*
  - *Eating4(Speaker, Desk)*
  - *Eating5(Speaker, Lunch)*
  - *Eating6(Speaker, TurkeySandwich, Lunch)*
  - *Eating7(Speaker, TurkeySandwich, Lunch, Desk)*
  - Relate them using meaning postulates:
    - $\forall w, x, y, z\ Eating7(w, x, y, z) \Rightarrow Eating6(w, x, y)$

Representation of Events

- Problems:
  - Need too many meaning postulates
  - Difficult to scale up
- Method 2:
  - Use a *single* predicate where as many arguments are included in the definition of the predicate as ever appear with it in an input

Representation of Events

- $\exists$ *w, x, y Eating(Speaker, w, x, y)*
- $\exists$ *w, x Eating(Speaker, TurkeySandwich, w, x)*
- $\exists$ *w Eating(Speaker, TurkeySandwich, w, Desk)*
- $\exists$ *w, x Eating(Speaker, w, x, Desk)*
- $\exists$ *w, x Eating(Speaker, w, Lunch, x)*
- $\exists$ *w Eating(Speaker, TurkeySandwich, Lunch, w)*
- *Eating(Speaker, TurkeySandwich, Lunch, Desk)*

Representation of Events

- Problems:
  - Make too many commitments
    - Need to commit to all arguments (e.g., every eating event must be associated with a meal, which is not true)
  - Unable to refer to individual events
    - Event is a predicate, not a term

Representation of Events

- Method 3:
  - Use reification to elevate events to objects
  - Arguments of an event appear as predicates
  - Do not need to commit to arguments (roles) not mentioned in the input
  - Meaning postulates not needed

Representation of Events

- I ate.
  - $\exists$ w *isa(w, Eating)* $\wedge$ *Eater(w, Speaker)*
- I ate a turkey sandwich.
  - $\exists$ *w isa(w, Eating)* $\wedge$ *Eater(w, Speaker)* $\wedge$ *Eaten(w, TurkeySandwich)*
- I ate a turkey sandwich for lunch.
  - $\exists$ *w isa(w, Eating)* $\wedge$ *Eater(w, Speaker)* $\wedge$ *Eaten(w, TurkeySandwich)* $\wedge$ *MealEaten(w, Lunch)*

Temporal Representations

- How do we represent time and temporal relationships between events?
  - *Last year Ali was happy but soon he will be sad.*
- Where do we get temporal information?
  - Verb tense
  - Temporal expressions
  - Sequence of presentation

Temporal Representations

- I arrived in New York.
  - $\exists$ *i, e, w isa(w, Arriving)* $\wedge$ *Arriver(w, Speaker)* $\wedge$ *Destination(w, NewYork)* $\wedge$ *IntervalOf(w, i)* $\wedge$ *EndPoint(i, e)* $\wedge$ *Precedes(e, Now)*
- I am arriving in New York.
  - $\exists$ *i, w isa(w, Arriving)* $\wedge$ *Arriver(w, Speaker)* $\wedge$ *Destination(w, NewYork)* $\wedge$ *IntervalOf(w, i)* $\wedge$ *MemberOf(i, Now)*
- I will arrive in New York.
  - $\exists$ *i, b, w isa(w, Arriving)* $\wedge$ *Arriver(w, Speaker)* $\wedge$ *Destination(w, NewYork)* $\wedge$ *IntervalOf(w, i)* $\wedge$ *BeginPoint(i, b)* $\wedge$ *Precedes(Now, b)*

Representations of Time (cont.)

- The relation between simple verb tenses and points in time is not straightforward.
  - We fly from Dhahran to Riyadh.
    - present tense refers to a future event
  - Flight 12 will be at gate an hour now.
    - future tense refers to a past event
- In some formalisms, the tense of a sentence is expressed with the relation among ***times of events (E)*** in that sentence, ***time of a reference point (R)***, and ***time of utterance (U)***.

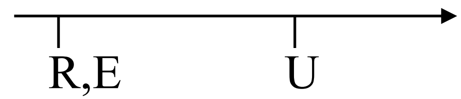
Reinhenbach's Approach to Representing Tenses

Past Perfect

I had eaten.

Past

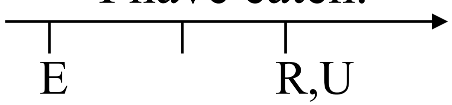
I ate.



- ***times of events (E)***
- ***time of a reference point (R)***
- ***time of utterance (U)***

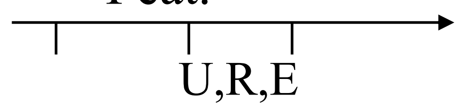
Present Perfect

I have eaten.



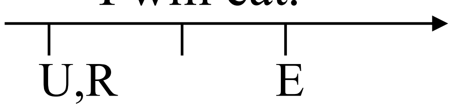
Present

I eat.



Future

I will eat.



Future Perfect

I will have eaten.

Aspects representation

- Aspects indicate relations between predicates and time.
  - Whether an event is conceptualized as happening at a point in time or over some time interval
  - Whether an event has ended or is ongoing
  - Whether any particular state comes about because of an event
- Event expressions: (based on the above)
  - Statives
  - Activities
  - Accomplishments
  - Achievements

Verbs and Event Types: Aspect

- **Statives**: states or properties of objects at a particular point in time
  - *Ali needs sleep.*
  - **Ali is needing sleep.*
  - **Need sleep.*
  - **Mary needs sleep in a week.*

•Odd When used in

•Progressive

•Imperative

•Not easily modified by adverbs like carefully

•Odd when modified with temporal expression using *in*

- **Activities**: events with no clear endpoint
  - *Ali drives a Porsche.*
  - **Ali drives a Porsche in a week.*

Verbs and Event Types: Aspect

- **Accomplishments**: events with durations and endpoints that result in some change of state
  - *Sami filled out the form.*
  - *Sami stopped filling out the form (Sami did not fill out the form) vs. Ali stopped driving a Porsche (Ali still drove a Porsche …for a while)*
- **Achievements**: events that change state but have no particular duration
  - *Asem reached the top.*
  - ** Asem stopped reaching the top.*
  - ** Asem reached the top for a few minutes.*

Aspects

- A verb can belong to different aspectual classes depending on the context
  - *I flew*. (activity)
  - *I flew to New York*. (accomplishment)

Beliefs

- In addition to the "real world", there are hypothetical world. Words such as: *believe, want, imagine, know* create speaker's hypothetical world.

I believe that Asem ate Saudi food.

FOPC: $\exists$ *u, v isa(u, believing)* $\wedge$ *isa(v, eating)* $\wedge$ *believer(u, speaker)* $\wedge$ *believedProp(u, v)* $\wedge$ *eater(v, Asem)* $\wedge$ *eaten(v, Saudifood)*

- There is a problem: every part of the above has to be true in order for the whole formula to be true
- But we don't know if this is true or not.

Beliefs

- How about a representation like this:

believing(Speaker, Eating(Asem , Saudifood))

- This is not FOPC, second argument is a formula not a term
- Predicates in FOPC hold between the objects in the domain being modeled, not between the relations that hold among the objects in the domain. Therefore, FOPC lacks a meaningful way to assert relations about full propositions.

Solution

- Introduce an operator, called *believes*, that takes two FOPC formulas as arguments, a formula for *believer*, and a formula for *believed proposition*.

Believes (speaker, $\exists$ *v isa (v, eating)* $\wedge$ *eater (v, Asem)* $\wedge$ *eaten (v, Saudifood))*

  - *Not FOPC*
  - Modal operators: *believe, want, imagine, know*
  - Modal Logic: is a logic augmented with modal operators

Frames

- We may use other representation languages instead of FOPC. But they will be equivalent to their representations in FOPC.
- For example, we may use **frames** to represent our *believing* example.

$$
\begin{bmatrix}
\text{BELIEVING} & \\
\text{BELIEVER} & \textit{Speaker} \\
\text{BELIEVED} & \begin{bmatrix} \text{EATING} & \\ \text{EATER} & \textit{Asem} \\ \text{EATEN} & \textit{SaudiFood} \end{bmatrix}
\end{bmatrix}
$$

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Lecture 21: Semantic Analysis

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Semantic Analysis

- Semantic analysis is the process of taking in some linguistic input and assigning a meaning representation to it.
  - Different ways
    - make use of syntax
  - We're going to start with the idea that syntax does matter
    - The compositional rule-to-rule approach

Compositional Analysis

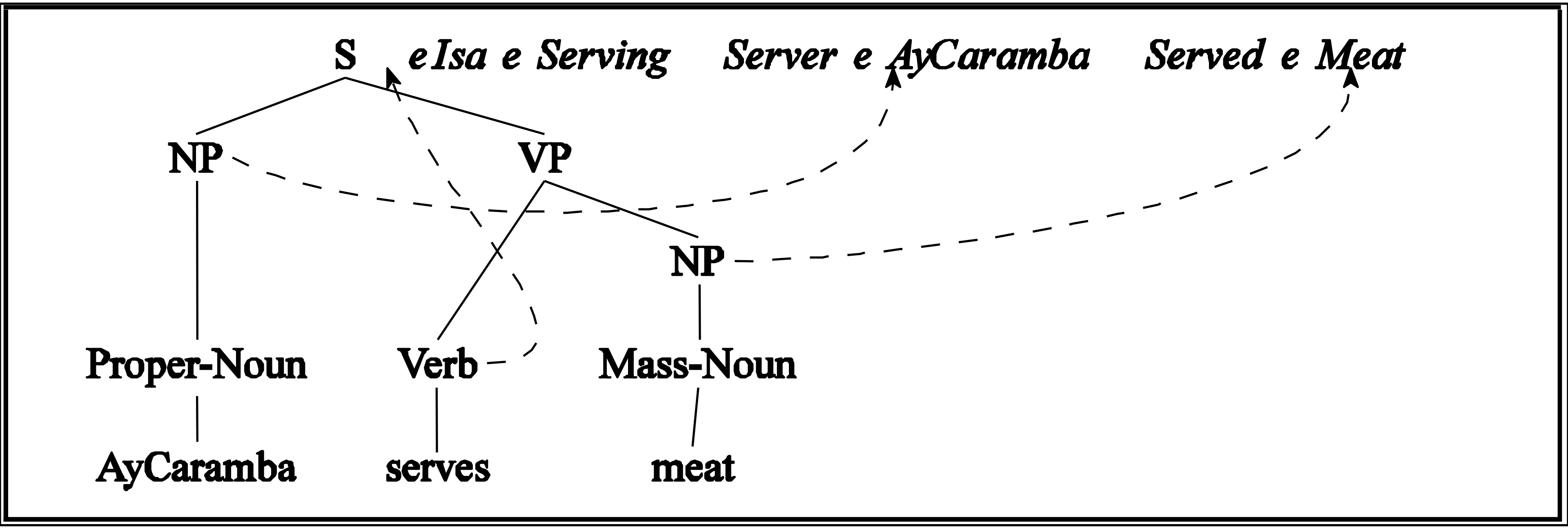
- Principle of Compositionality
  - The meaning of a whole is derived from the meanings of the parts
- What parts?
  - Account for the meaning not solely for the words, but also Syntactic Components and Relations
    - Ordering
    - Grouping
    - Relations among the words
  - The constituents of the syntactic parse of the input

Example

- AyCaramba serves meat

$$\exists e\ Serving(e) \wedge Server(e, AyCaramba) \wedge Served(e, Meat)$$

Compositional Analysis



Augmented Rules

- We'll accomplish this by attaching semantic formation rules to our syntactic CFG rules
- Abstractly

$$A \rightarrow \alpha_1 \ldots \alpha_n \qquad \{f(\alpha_1.sem, \ldots \alpha_n.sem)\}$$

- This should be read as the semantics we attach to A can be computed from some function applied to the semantics of A's parts.

Example

- Easy parts…
  - NP → PropNoun
  - NP → MassNoun
  - PropNoun → AyCaramba
  - MassMoun → meat
- Attachments

  {PropNoun.sem}

  {MassNoun.sem}

  {AyCaramba}

  {meat}

- These attachments consist of assigning constants and copying from daughters up to mothers.

Example

- $S \rightarrow NP\ VP$
- $VP \rightarrow Verb\ NP$
- $Verb \rightarrow serves$

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

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

These consist of taking the semantics attached to one daughter and applying it as a function to the semantics of the other daughters.

Lambda Forms

- A simple addition to FOPC
  - Take an FOPC sentence with variables in it that are to be bound.
  - Allow those variables to be bound by treating the lambda form as a function with formal arguments

$$\lambda x P(x)$$

$$\lambda x P(x)(Sally)$$

$$P(Sally)$$

Lambda Forms

$$\lambda x\, \lambda y In(x, y) \wedge Country(y)$$

$$\lambda x\, \lambda y In(x, y) \wedge Country(y)(BC)$$

$$\lambda y In(BC, y) \wedge Country(y)$$

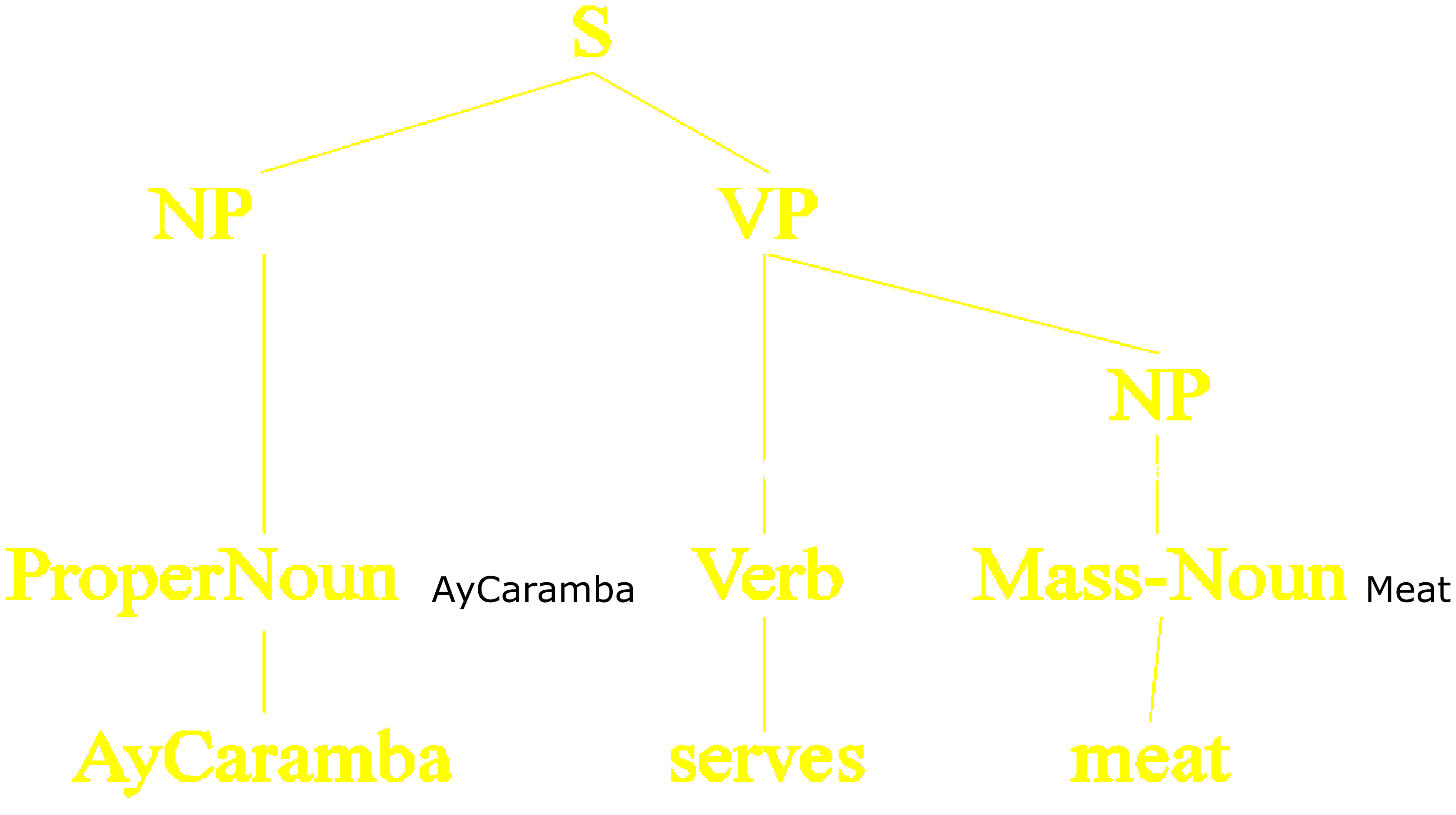
$$\lambda y In(BC, y) \wedge Country(y)$$

$$\lambda y In(BC, y) \wedge Country(y)(CANADA)$$

$$In(BC, CANADA) \wedge Country(CANADA)$$

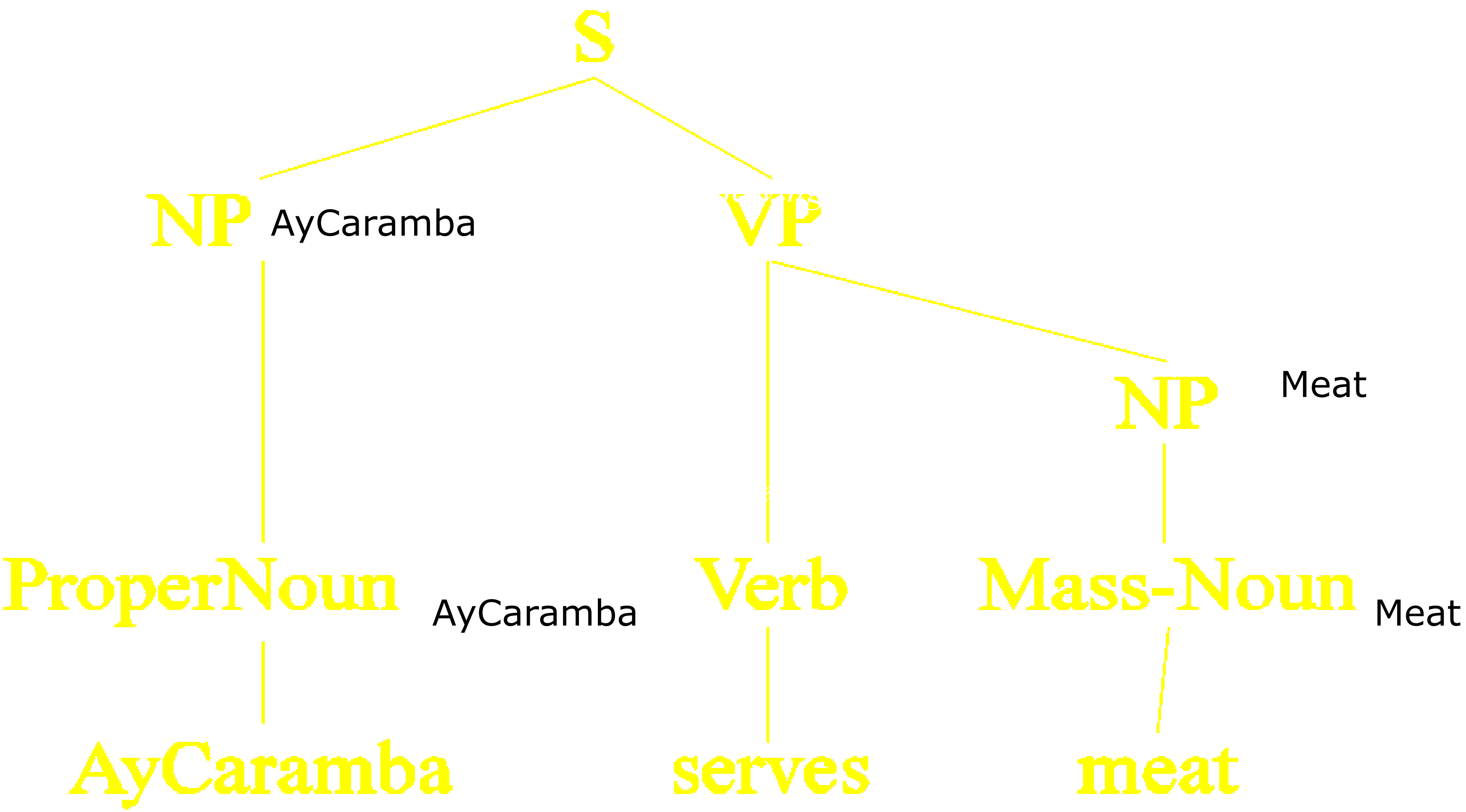
Example

Example



S
NP
VP
NP
ProperNoun
AyCaramba
Verb
Mass-Noun
Meat
AyCaramba
serves
meat

Example



S
NP
AyCaramba
VP
NP
Meat
ProperNoun
AyCaramba
Verb
Mass-Noun
Meat
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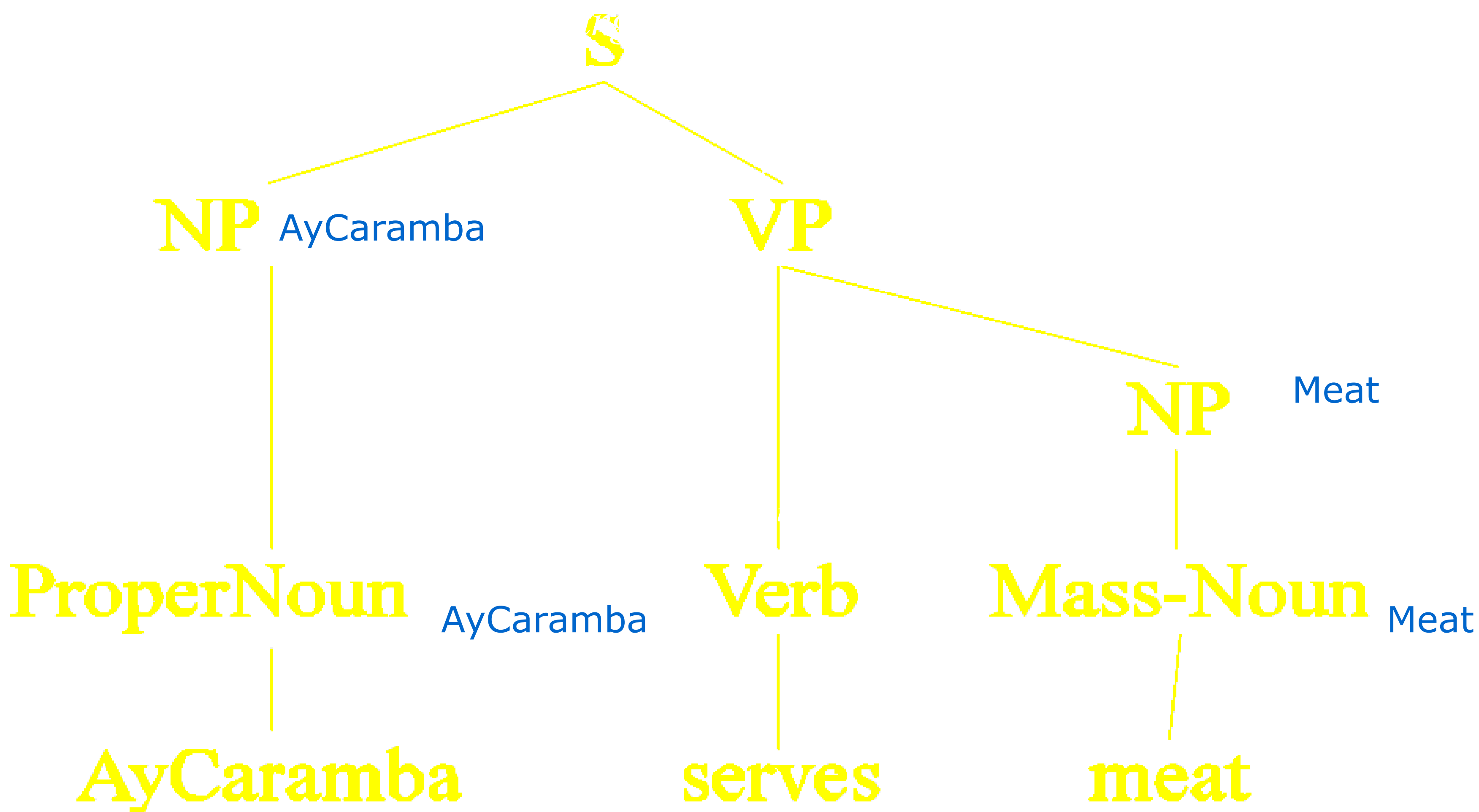
Example


S
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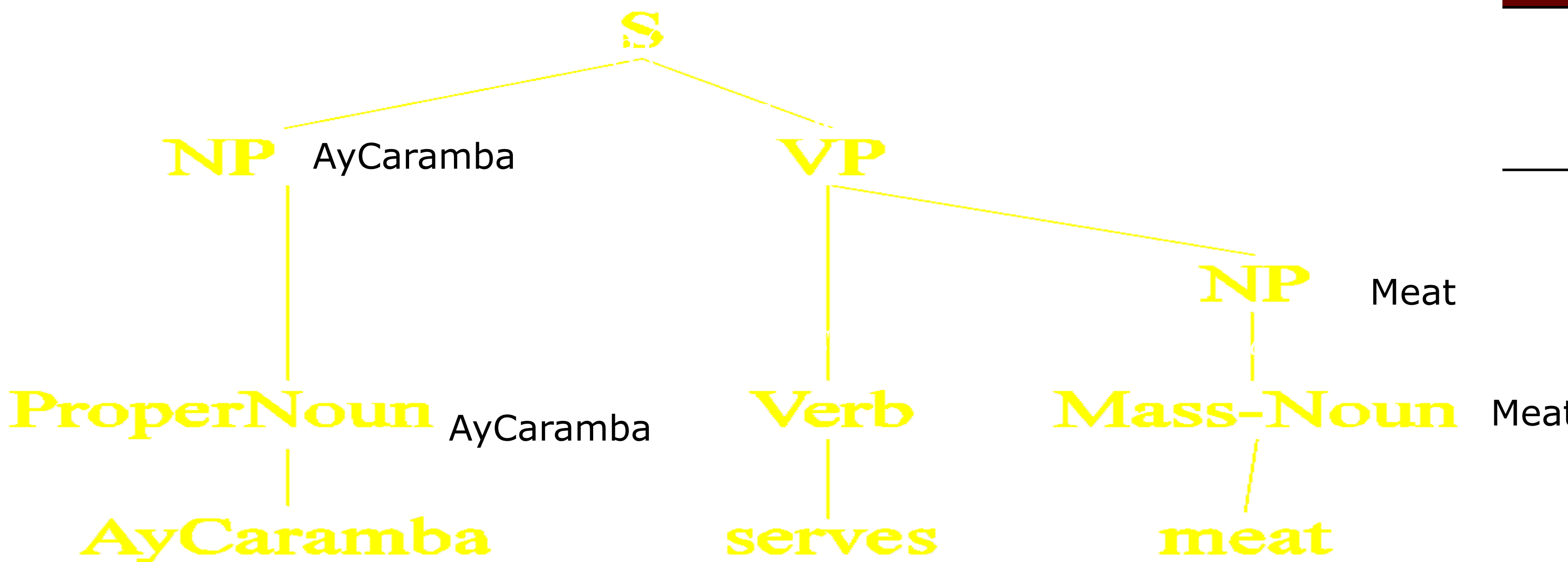

- **S → NP VP** — **{VP.sem(NP.sem)}**
- **VP → Verb NP** — **{Verb.sem(NP.sem)}**
- **Verb → serves** — $\lambda x\, \lambda y\; \exists e\; Serving(e) \wedge Server(e, y) \wedge Served(e, x)$
- **NP → PropNoun** — **{PropNoun.sem}**
- **NP → MassNoun** — **{MassNoun.sem}**
- **PropNoun → *AyCaramba***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

Thank you

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