Artificial Intelligence -- 15-381
Natural Language Processing

Jaime Carbonell
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OUTLINE:

- Overview of NLP Tasks[1]
- Parsing: Augmented Transition Networks
- Parsing: Case Frame Instantiation
- Intro to Machine Translation

[1]There will be a new course in 15-4xxx and 16-682 in the fall: NLP, MT, IR, speech, web apps

Natural Language Processing In a Nutshell

Objectives

- To study the nature of language (Linguistics)
- As a window into cognition (Psychology)
- As an human-interface technology (HCI)
- As a technology for text translation (MT)
- As a technology for information management (IR)

Component Technologies: Text NLP

- Parsing: text -> internal representation
  such as parse trees, frames, FOL, ...
- Generation: representation -> text
- Inference: representation -> fuller representation
- Filter: huge volumes text -> relevant-only text
- Summarize: clustering, extraction, presentation

Component Technologies: Speech NLP

- Speech recognition: acoustics -> text
- Speech synthesis: text -> acoustics
- Language modeling: text -> p(text | context)
- ...and all the text components

AMBIGUITY MAKES NATURAL LANGUAGE PROCESSING HARD

Syntactic

I saw the Grand Canyon flying to New York
Time flies like an arrow

Word Sense

The man went to the **bank** *to get some cash*
and jumped in

Case

He ran the mile **in** *four minutes*
the Olympics

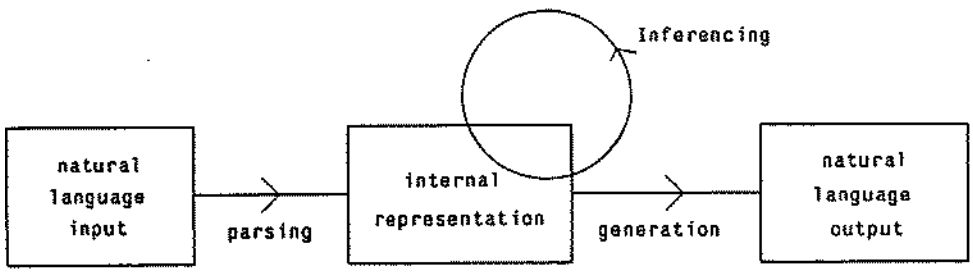
Referential

I took the cake from the table and cleaned **it.**
ate **it.**

Indirect Speech Acts

Can you open the door?
I feel cold.

OUTLINE OF A NATURAL LANGUAGE PROCESSING SYSTEM

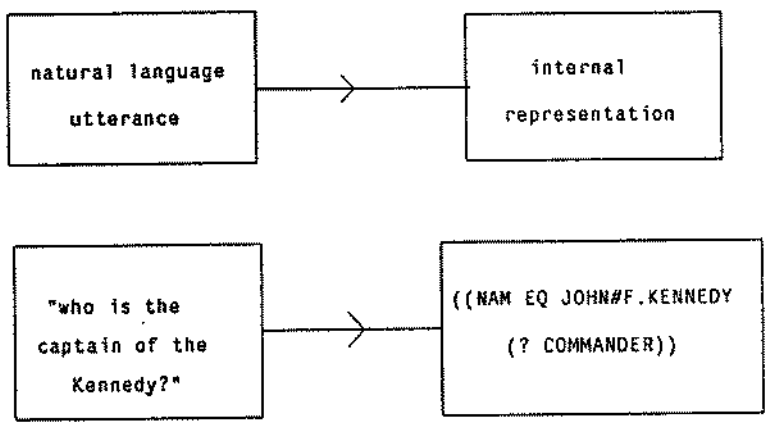


Natural language processing involves translation of input into an unambiguous internal representation before any further inferences can be made or any response given.

In applied natural language processing:

- little additional inference is necessary after initial translation
- canned text templates can often provide adequate natural language output
- so translation into internal representation is central problem.

TRANSLATION INTO INTERNAL REPRESENTATION



Examples of representations:

- db query language (for db access)
- parse trees with word sense terminal nodes (for machine translation)
- case frame instantiations (for a variety of applications)
- lisp s-expressions (for expert system requests)
- conceptual dependency (for story understanding)

Parsing in NLP

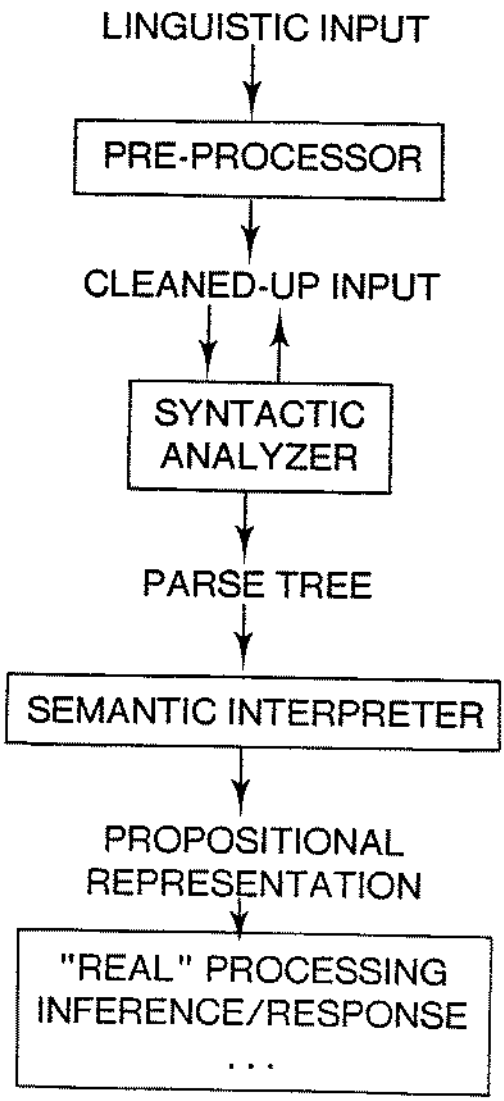
Parsing Technologies

1. Parsing by template matching (e.g. ELIZA)
2. Parsing by direct grammar application (e.g. LR)
3. Parsing with Augmented Transition Networks (ATNs)
4. Parsing with Case Frames (e.g. DYPAR)
5. Unification-Based parsing methods (e.g. GLR/LFG)
6. Robust parsing methods (e.g. GLR*)

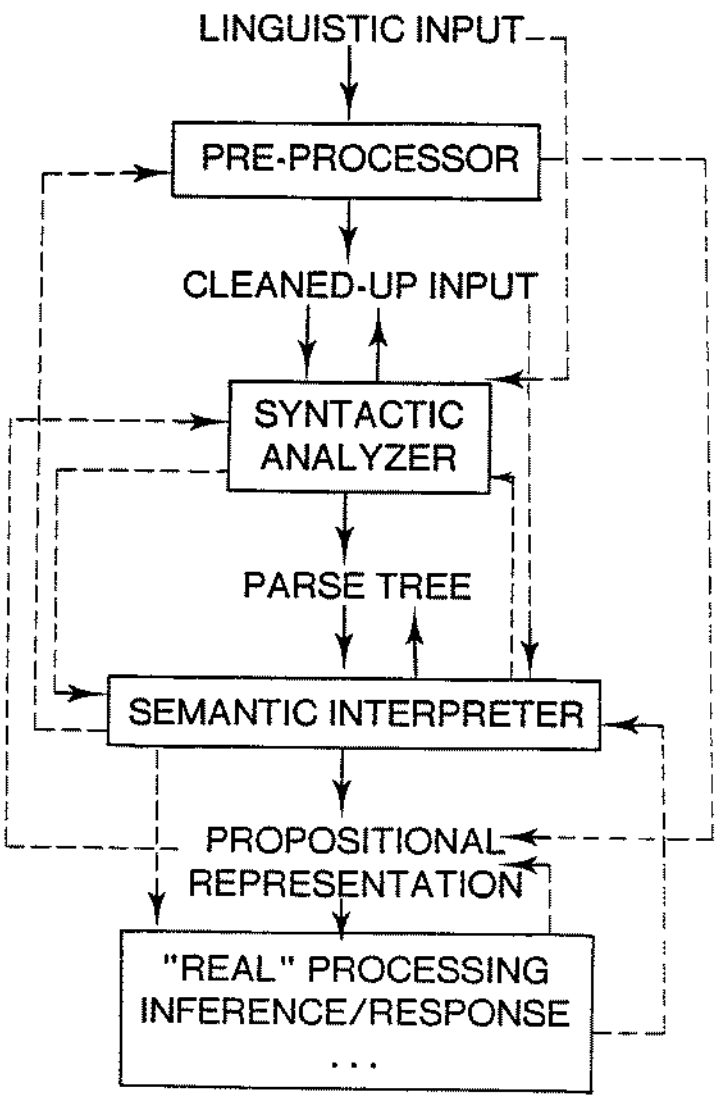
Parsing Complexity

- Unambiguous Context-Free => $O(n^2)$ (e.g. LR)
- General CF => $O(n^3)$ (e.g. Early)
- Context-Sensitive => $O(2^n)$
- NLP is "mostly" Context Free.
- Semantic constraints reduce average case complexity.
  In practice: $O(n^2) < O(NLP) < O(n^3)$

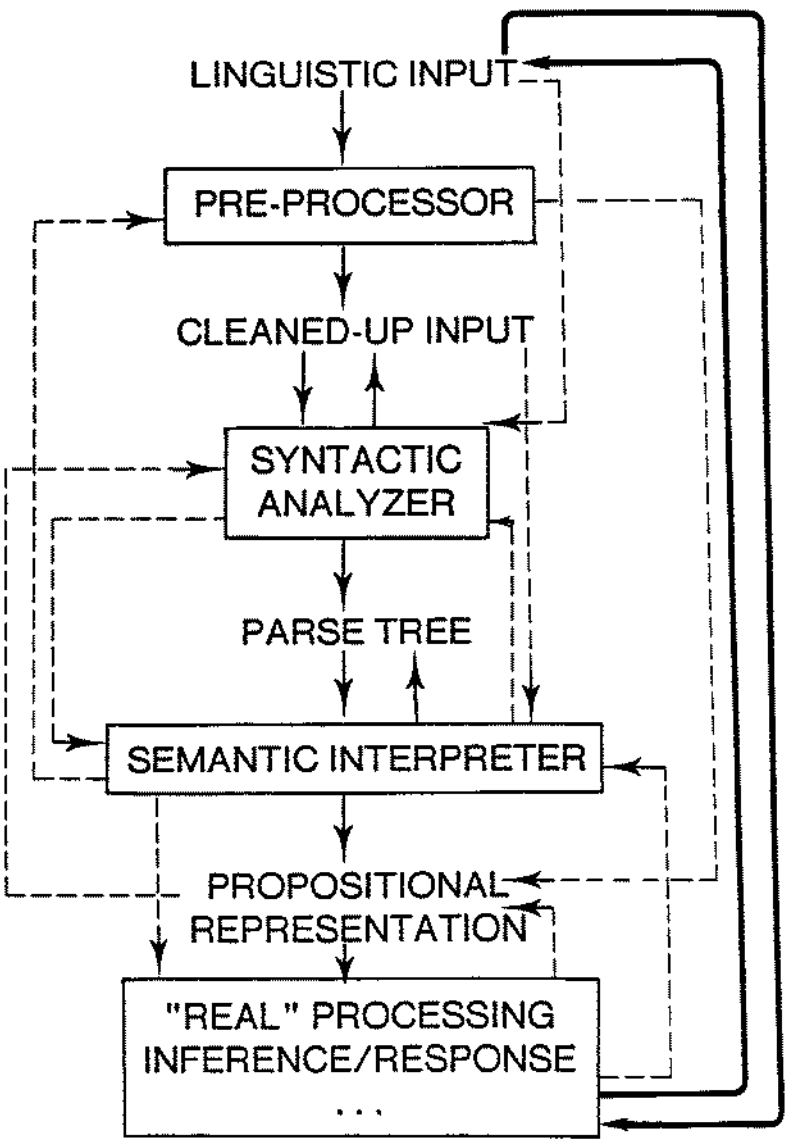
CLASSICAL PERIOD



BAROQUE PERIOD



RENAISSANCE



CONTEXT-FREE GRAMMARS

Example:

S → NP VP
NP → DET N | DET ADJ N
VP → V NP
DET → the
ADJ → big | green
N → rabbit | rabbits | carrot
V → nibbled | nibbles | nibble

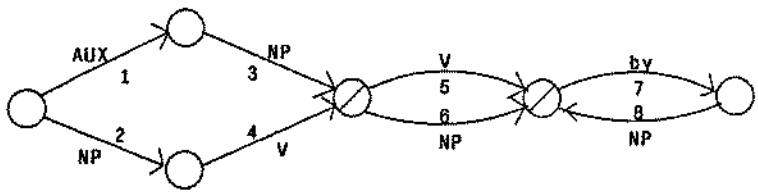
Advantages:

- Simple to define
- Efficient parsing algorithms

Disadvantages:

- Can't enforce agreements in a concise way
- Can't capture relationships between similar utterances (e.g. passive and active)
- No semantic checks (as in all syntactic approaches)

EXAMPLE ATN



1	T	(SETR V *) (SETR TYPE 'QUESTION)
2	T	(SETR SUBJ *) (SETR TYPE 'DECLARATIVE)
3	(agrees * V)	(SETR SUBJ *)
4	(agrees SUBJ *)	(SETR V *)
5	(AND (GETF PPRT) (= V 'BE))	(SETR OBJ SUBJ) (SETR V *) (SETR AGFLAG T) (SETR SUBJ 'SOMEONE)
6	(TRANS V)	(SETR OBJ *)
7	AGFLAG	(SETR AGFLAG FALSE)
8	T	(SETR SUBJ *)

LIFER SEMANTIC GRAMMARS

Example domain — access to DB of US Navy ships

S	→	<present> the <attribute> of <ship>
<present>	→	what is | [can you] tell me
<attribute>	→	length | beam | class
<ship>	→	the <shipname>
<shipname>	→	kennedy | enterprise
<ship>	→	<classname> class ship
<classname>	→	kitty hawk | lafayette

Example inputs recognized by above grammar:

what is the length of the Kennedy
can you tell me the class of the Enterprise
what is the length of Kitty Hawk class ships

- Not all categories are "true" syntactic categories
- Words are recognized by their context rather than category (e.g. *class*)
- Recognition is strongly directed
- Strong direction useful for spelling correction

SEMANTIC GRAMMAR SUMMARY

Advantages:

- Efficient recognition of limited domain input
- Absence of overall grammar allows pattern-matching possibilities for idioms, etc.
- No separate interpretation phase
- Strength of top-down constraints allow powerful ellipsis mechanisms

  What is the length of the Kennedy?
  The beam?

Disadvantages:

- Different grammar required for each new domain
- Lack of overall syntax can lead to "spotty" grammar coverage
  (e.g. fronting possessive in "<attribute> of <ship>") doesn't imply fronting in "<rank> of <officer>")
- Difficult to develop grammars
- Suffers from same fragility as ATNs

CASE FRAMES

Case frames were introduced by Fillmore (a linguist) to account for essential equivalence of sentences like:

- John broke the window with a hammer
- A hammer broke the window
- The window broke

```
[head: BREAK
 agent: JOHN
 object: WINDOW
 instrument: HAMMER
]
```

Fillmore postulated finite set of cases applicable to all actions

```
[head: <the action>
 agent: <the active causal agent instigating the action>
 object: <the object upon which the action is done>
 instrument: <an instrument used to assist in the action>
 recipient: <the receiver of an action - often the I-OBJ>
 directive: <the target of an (usually physical) action>
 locative: <the location where the action takes place>
 benefactive: <the entity for whom the action is taken>
 co-agent: <a secondary or assistant active agent>
]
```

CONCEPTUAL DEPENDENCY

- Canonical representation of natural language developed by Schank
- Computational motivation — organization of inferences

```
[ATRANS
  rel:  POSSESSION
  actor:  JOHN
  object:  BALL
  source:  JOHN
  recipient:  MARY]
```

"John gave Mary a ball"

```
[ATRANS
  rel:  POSSESSION
  actor:  MARY
  object:  BALL
  source:  JOHN
  recipient:  MARY]
```

"Mary took a ball from John"

```
[ATRANS                                  [ATRANS
  rel:  OWNERSHIP        CAUSE             rel:  OWNERSHIP
  actor:  JOHN           ------>           actor:  MARY
  object:  APPLE         <------           object:  26 CENTS
  source:  JOHN          CAUSE             source:  MARY
  recipient:  MARY]                        recipient: JOHN]
```

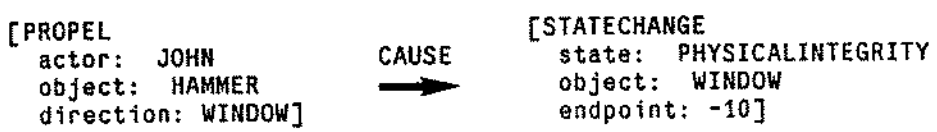
"John sold an apple to Mary for 26 cents"

Other conceptual dependency primitive actions include:

PTRANS	Physical transfer of location
MTRANS	Mental transfer of information
MBUILD	Create a new idea or conclusion from other information
INGEST	Bring any substance into the body
PROPEL	Apply a force to an object

States and *causal* relations are also part of the representation:

```
ENABLE   (State enables an action)
RESULT   (An action results in a state change)
INITIATE (State or action initiates mental state)
REASON   (Mental state is the internal reason for an action)
```



"John broke the window with a hammer"

ROBUST PARSING

Spontaneously generated input will contain errors and items outside an interface's grammar

- spelling errors

  tarnsfer *Jim Smith from* **Econoics** *237*
  too *Mathematics 156*

- novel words

  transfer Smith out of Economics 237
  to **Basketwork** *100*

- spurious phrases

  please *enroll Smith* **if that's possible**
  in **I think** *Economics 237*

- ellipsis or other fragmentary utterances

  also Physics 314

- unusual word order

  in Economics 237 Jim Smith enroll

- missing words

  enroll Smith Economics 237

BAR HILLEL'S ARGUMENT

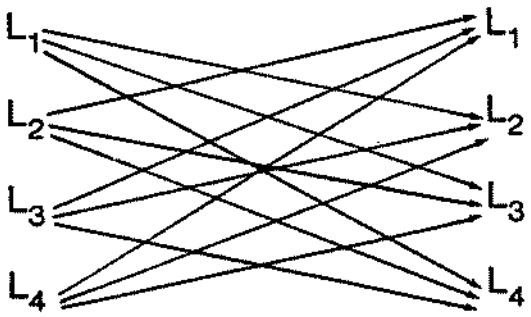
1. Text must be (minimally) understood before translation can proceed effectively.
2. Computer understanding of text is too difficult
3. Therefore, Machine Translation is infeasible

- Bar Hillel (1960)

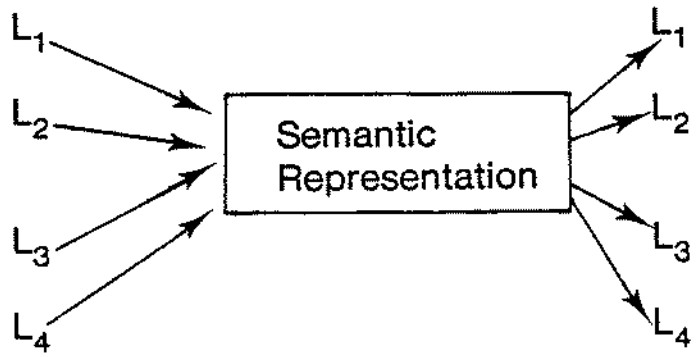
- Premise 1 is accurate.
- Premise 2 *was* accurate in 1960.

Some forms of text comprehension are becoming possible with present AI technology, but we have a long way to go. Hence, Bar Hillel's conclusion is losing its validity, but only gradually.

Transfer Grammars: N(N-1)



KBMT Approach: 2N



For N = 72, T/G = 5,112, KBMT = 144 Processes

Beyond parsing, generation and MT

Anaphora and Ellipsis Resolution

- "Mary got nice present from Cindy. ***It*** was ***her*** birthday."
- "John likes oranges and Mary apples"

Dialog Processing

- "Speech Acts" (literal -> intended message)
- Social Role context -> speech act selection
- "General" context sometimes needed

Example

10-year old: "I want a juicy Hamburger!"
Mother: "Not today, perhaps tomorrow..."

General: "I want a juicy Hamburger."
Aide: "Yes, sir!!"

Prisoner 1: "I want a juicy hamburger."
Prisoner 2: "Wouldn't that be nice for once."

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—National Smoker Study

Majority of smokers confirm 'Enriched Flavor' cigarette matches taste of leading high tar brands.