Semantic Role Labeling

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28 Aug 2019

Semantic role labeling (SRL)

- The task of finding the semantic roles of each argument of each predicate in a sentence.

[You]	can't	[blame]	[the program]	[for being unable to identify it]
COGNIZER		TARGET	EVALUEE	REASON

A useful shallow semantic representation

Improves NLP tasks like:

- question answering
- machine translation

SRL and Syntactic Cues

- Frequently semantic role is indicated by a particular syntactic position (e.g. object of a particular preposition).
  - Agent: subject
  - Patient: direct object
  - Instrument: object of “with” PP
  - Beneficiary: object of “for” PP
  - Source: object of “from” PP
  - Destination: object of “to” PP
- However, these are preferences at best:
  - The hammer hit the window.
  - The book was given to Mary by John.
  - John went to the movie with Mary.
  - John bought the car for $21K.
  - John went to work by bus.

Selectional Restrictions

- Selectional restrictions are constraints that certain verbs place on the filler of certain semantic roles.
  - Agents should be animate
  - Beneficiaries should be animate
  - Instruments should be tools
  - Patients of “eat” should be edible
  - Sources and Destinations of “go” should be places.
  - Sources and Destinations of “give” should be animate.
- Taxanomic abstraction hierarchies or ontologies (e.g. hypernym links in WordNet) can be used to determine if such constraints are met.
  - “John” is a “Human” which is a “Mammal” which is a “Vertebrate” which is an “Animate”

Use of Selectional Restrictions

- Selectional restrictions can help rule in or out certain semantic role assignments.
  - "John bought the car for $21K"
    - Beneficiaries should be Animate
    - Instrument of a "buy" should be Money
  - "John went to the movie with Mary"
    - Instrument should be Inanimate
  - "John drove Mary to school in the van"

    "John drove the van to work with Mary."
    - Instrument of a "drive" should be a Vehicle

Selectional Restrictions and Syntactic Ambiguity

- Many syntactic ambiguities like PP attachment can be resolved using selectional restrictions.
  - "John ate the spaghetti with meatballs."

    "John ate the spaghetti with chopsticks."
    - Instruments should be tools
    - Patients of "eat" must be edible
  - "John hit the man with a dog."

    "John hit the man with a hammer."
    - Instruments should be tools

Selectional Restrictions and Word Sense Disambiguation

- Many lexical ambiguities can be resolved using selectional restrictions.
- Ambiguous nouns
  - "John wrote it with a pen."
    - Instruments of "write" should be WritingImplements
  - "The bat ate the bug."
    - Agents (particularly of "eat") should be animate
    - Patients of "eat" should be edible
- Ambiguous verbs
  - "John fired the secretary."

    "John fired the rifle."
    - Patients of DischargeWeapon should be Weapons
    - Patients of CeaseEmploment should be Human

Empirical Methods for SRL

- Difficult to acquire all of the selectional restrictions and taxonomic knowledge needed for SRL.
- Difficult to efficiently and effectively apply knowledge in an integrated fashion to simultaneously determine correct parse trees, word senses, and semantic roles.
- Statistical/empirical methods can be used to automatically acquire and apply the knowledge needed for effective and efficient SRL.

Supervised SRL

- SRL as a supervised machine learning problem
  - Classify words into predicates and non-predicates;
  - Classify non-predicates into arguments and non-arguments;
  - Classify arguments into their types.

1. Parse the sentence
2. Find predicates in the parsed sentence;
3. For each predicate
   - prune the remaining words, deleting those which for sure are not arguments
   - for each of the remaining words:
     - identify whether it is an argument/adjunct of the current predicate or not;
     - if yes, classify it (`local scoring').

Supervised Semantic Role Labeling

- Train a classifier that for each predicate:
  - determine for each synt. constituent which semantic role (if any) it plays with respect to the predicate
- Train on a corpus annotated with relevant constituent features

Features: predicate, phrase type, head word and its POS, path, voice, linear position…… *and many others*

Algorithm

function SEMANTICROLELABEL(*words*) **returns** labeled tree

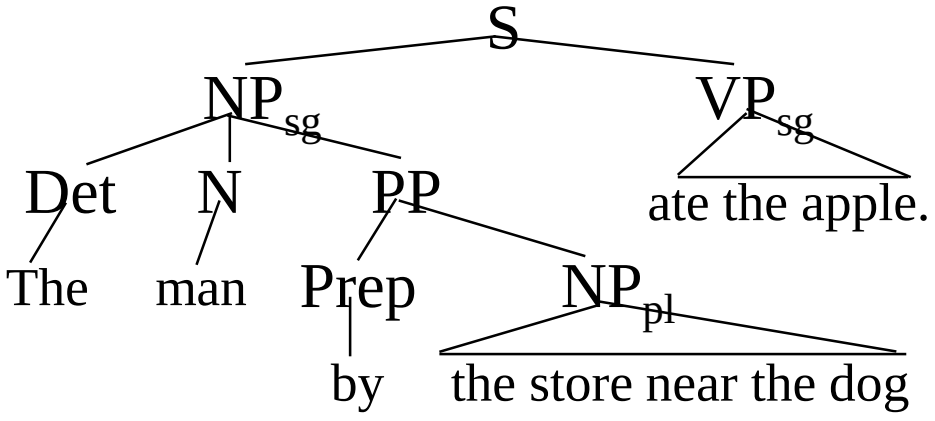
parse ← PARSE(*words*)
for each *predicate* **in** *parse* **do**
  for each *node* **in** *parse* **do**
    featurevector ← EXTRACTFEATURES(*node*, *predicate*, *parse*)
    CLASSIFYNODE(*node*, *featurevector*, *parse*)

SRL as Sequence Labeling

- SRL can be treated as an sequence labeling problem.
- For each verb, try to extract a value for each of the possible semantic roles for that verb.
- Employ any of the standard sequence labeling methods
  - Token classification
  - HMMs
  - CRFs
  - Neural methods (e.g., Bi-LSTM)

SRL with Parse Trees

- Parse trees help identify semantic roles through exploiting syntactic clues like “the agent is usually the subject of the verb”.
- Parse tree is needed to identify the true subject.



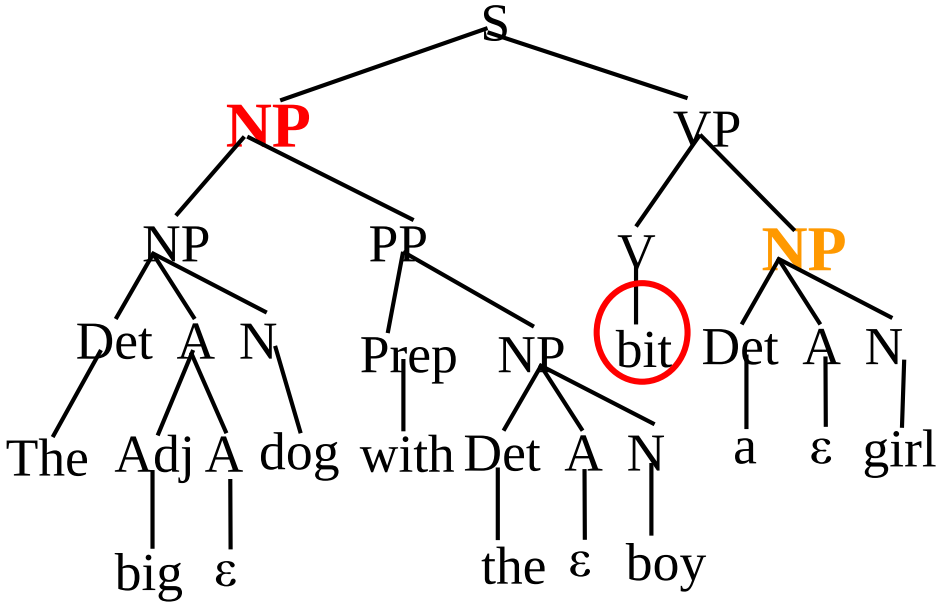
“The man by the store near the dog ate an apple.”
“The man” is the agent of “ate” not “the dog”.

SRL with Parse Trees

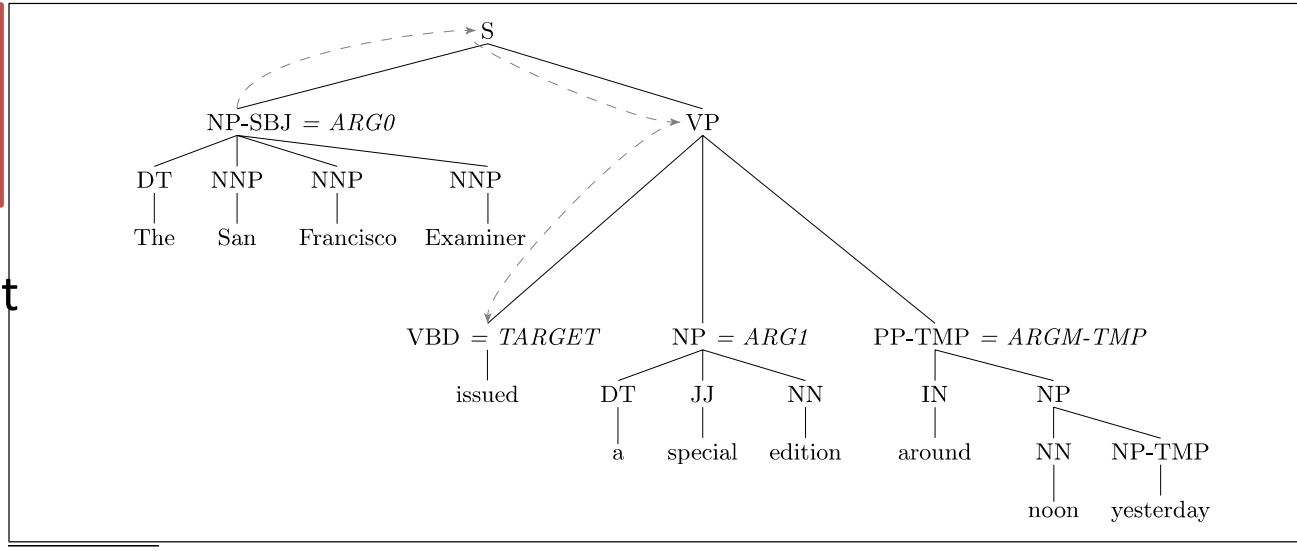
- Assume that a syntactic parse is available.
- For each predicate (verb), label each node in the parse tree as either not-a-role or one of the possible semantic roles.

Color Code:

not-a-role
agent
patient
source
destination
instrument
beneficiary



Features



Headword of constituent

Examiner

Headword POS

NNP

Voice of the clause

Active

Subcategorization of pred

VP -> VBD NP PP

Named Entity type of constituent

ORGANIZATION

First and last words of constituent

The, Examiner

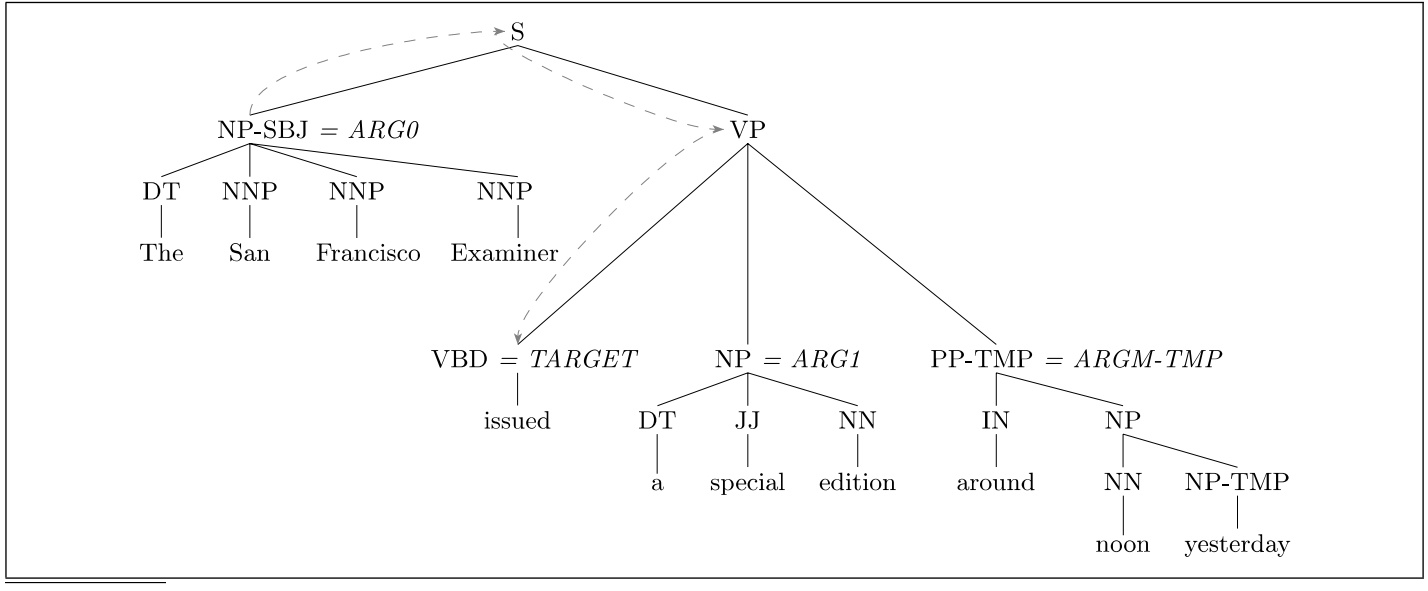
Linear position,clause re: predicate

before

Path Features

Path in the parse tree from the constituent to the predicate

NP↑S↓VP↓VBD



Frequent path features

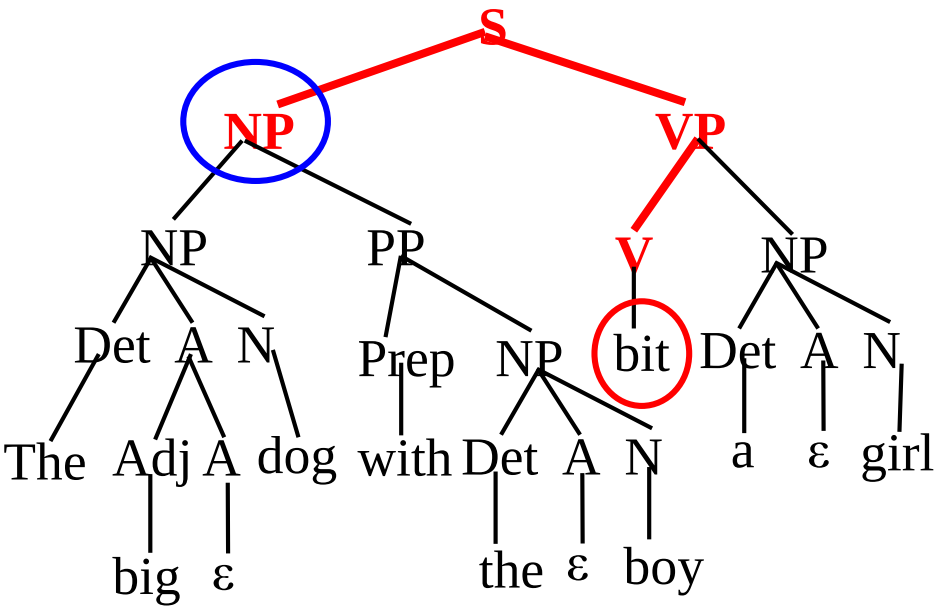
Frequency	Path	Description
14.2%	VB↑VP↓PP	PP argument/adjunct
11.8	VB↑VP↑S↓NP	subject
10.1	VB↑VP↓NP	object
7.9	VB↑VP↑VP↑S↓NP	subject (embedded VP)
4.1	VB↑VP↓ADVP	adverbial adjunct
3.0	NN↑NP↑NP↓PP	prepositional complement of noun
1.7	VB↑VP↓PRT	adverbial particle
1.6	VB↑VP↑VP↑VP↑S↓NP	subject (embedded VP)
14.2		no matching parse constituent
31.4	Other	

From Palmer, Gildea, Xue 2010

Parse Tree Path Feature: Example 1

Path Feature Value:

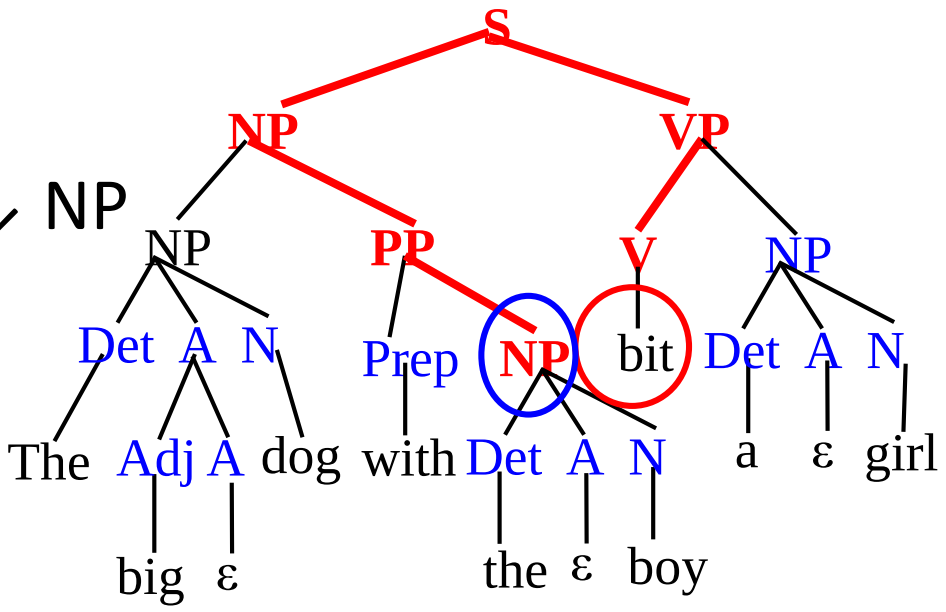
V ↑ VP ↑ S ↓ NP



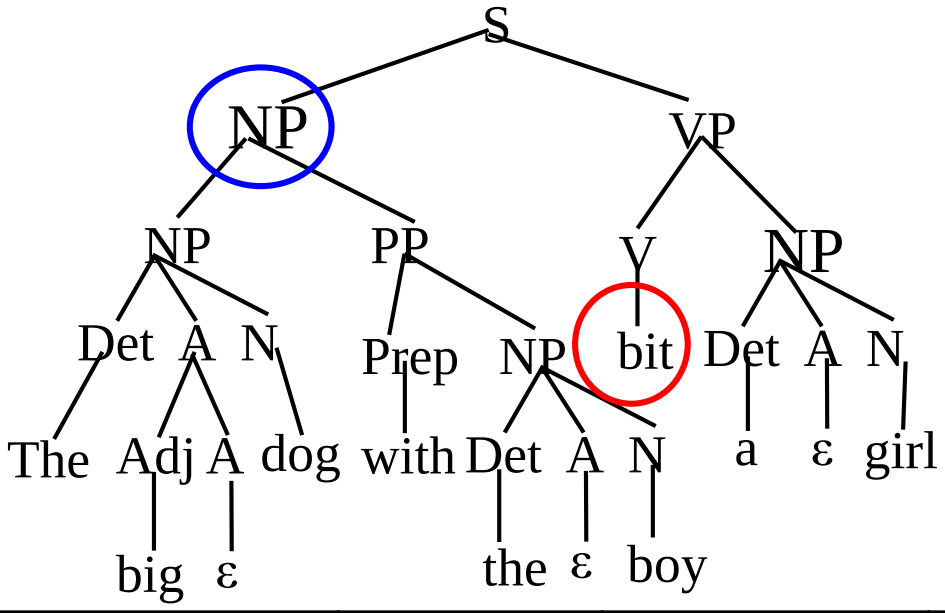
Parse Tree Path Feature: Example 2

Path Feature Value:

V ↑ VP ↑ S ↓ NP ↓ PP ↓ NP



Complete SRL Example



Phrase type	Parse Path	Position	Voice	Head word
NP	**V↑VP↑S↓NP**	precede	active	dog

Neural Approach

BIO/IOB labeling..

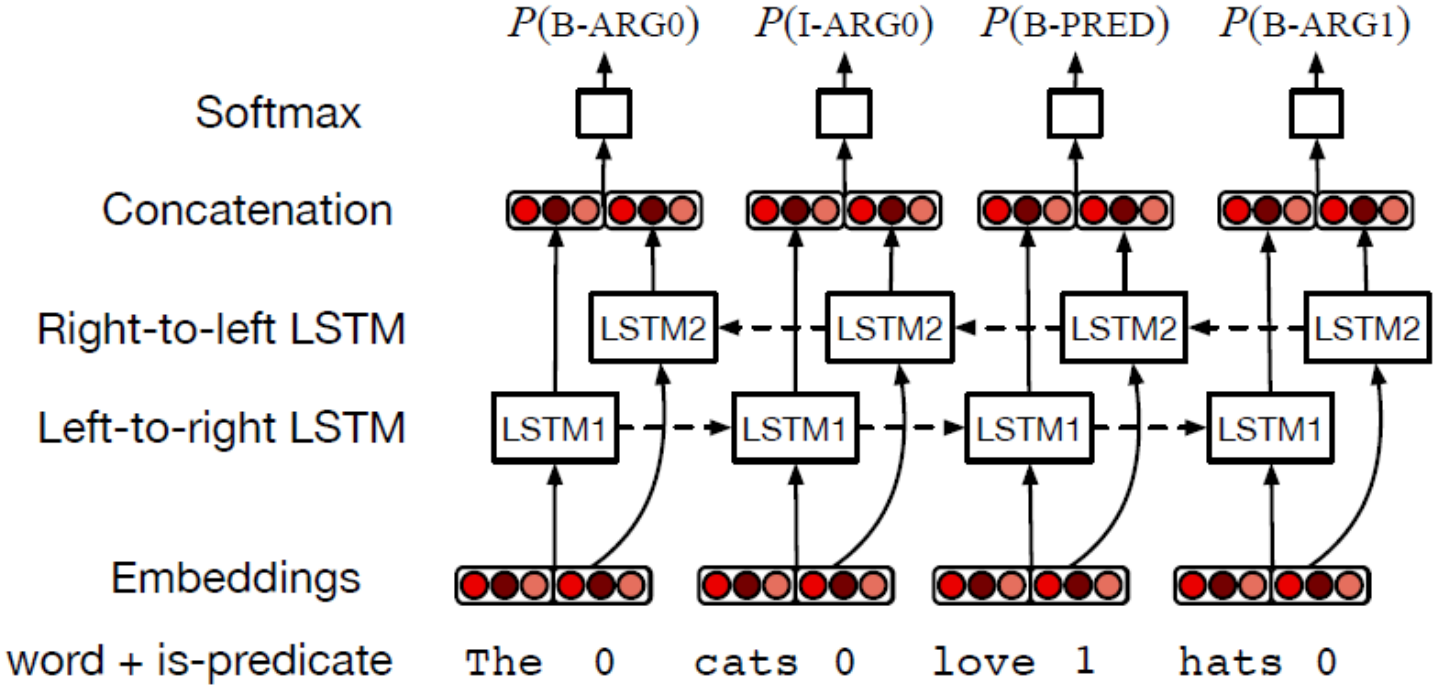
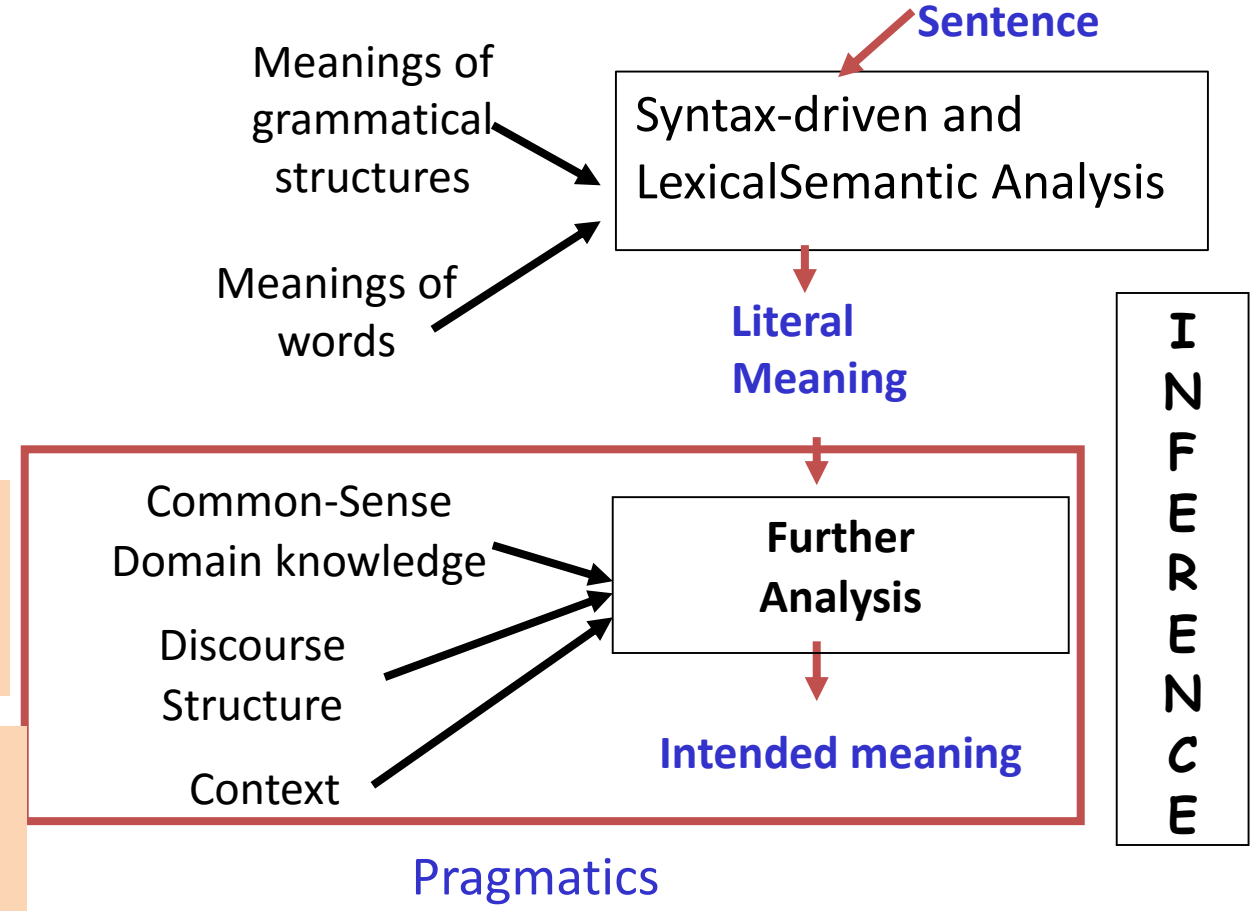


Figure 18.6 A bi-LSTM approach to semantic role labeling. Most actual networks are much deeper than shown in this figure; 3 to 4 bi-LSTM layers (6 to 8 total LSTMs) are common. The input is a concatenation of an embedding for the input word and an embedding of a binary variable which is 1 for the predicate to 0 for all other words. After He et al. (2017).

Issues in SRL

- How to properly integrate syntactic parsing, WSD, and role assignment so they all aid each other.
- How can SRL be used to aid end-use applications:
  - Question answering
  - Machine Translation
  - Text Mining

“Semantic” Analysis



Beyond single sentence…. Dialog…Paragraphs

User/speaker task, location, (mutual)beliefs, attitudes…