# Semantic Role Labeling

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# 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 nonpredicates;
  - Classify non-predicates into arguments and non-arguments;
  - Classify arguments into their types.

- 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)

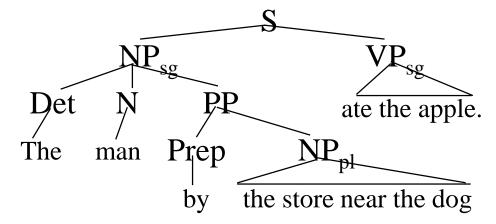
CLASSIFYNODE(node, featurevector, parse)
```

# 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 <u>ate</u> 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

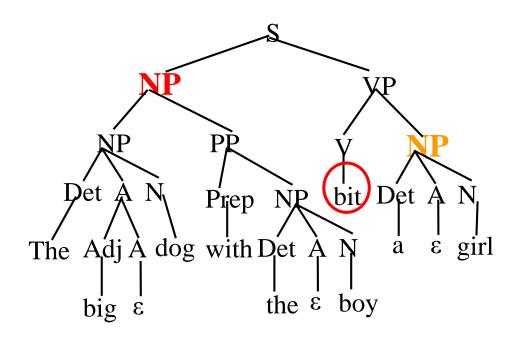
agent

patient

source

destination instrument

beneficiary



#### **Features**

Headword of constituent

Examiner

**Headword POS** 

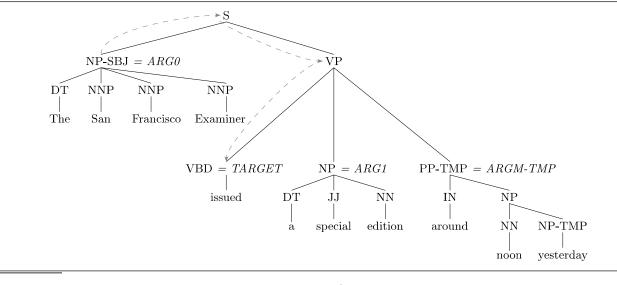
**NNP** 

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

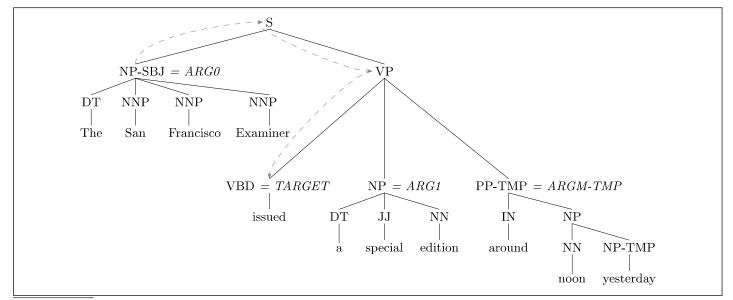
Linear position, clause re: predicate

before

### Path Features

**Path** in the parse tree from the constituent to the predicate

#### $NP\uparrow S\downarrow VP\downarrow VBD$



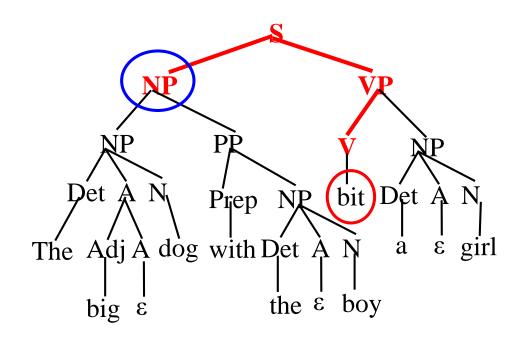
# Frequent path features

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	

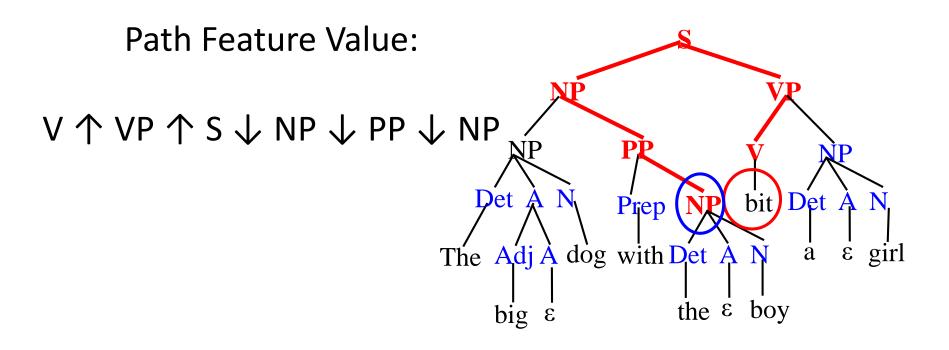
#### Parse Tree Path Feature: Example 1

Path Feature Value:

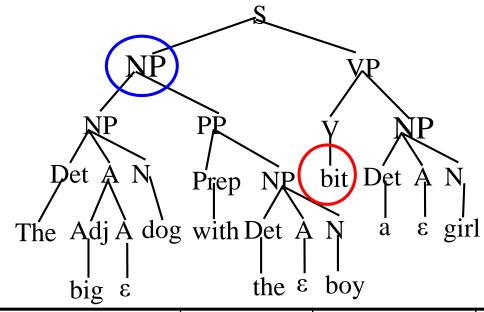
V ↑ VP ↑ S ↓ NP



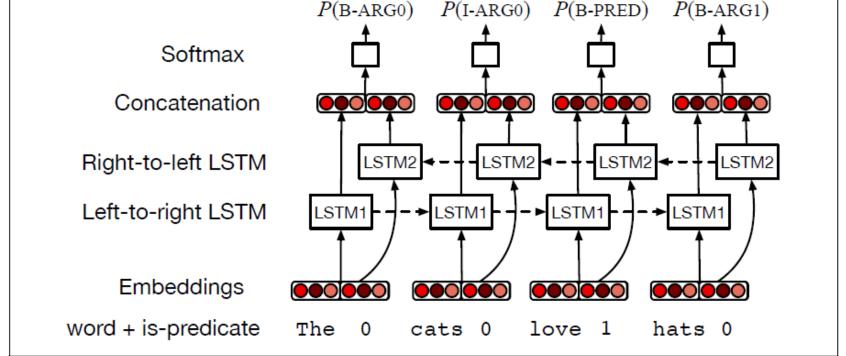
# Parse Tree Path Feature: Example 2



# Complete SRL Example



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

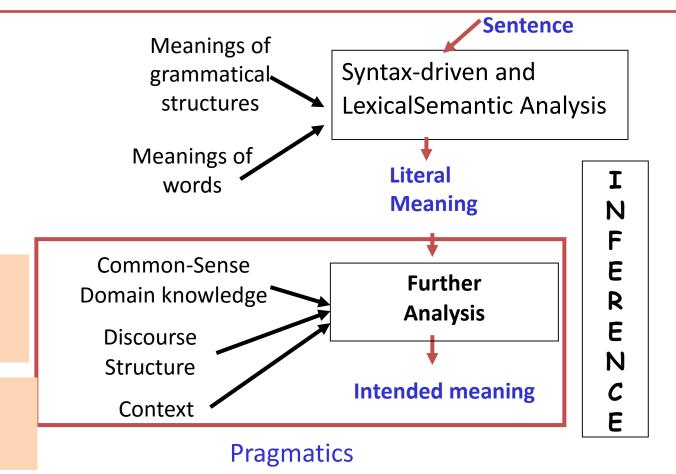


**Figure 18.6** A bi-LSTM approach to semantic role labeling. Most actual networks are much deeper than shown in this figure; 3 to 4 bi-LSTM layers (6 to 8 total LSTMs) are common. The input is a concatenation of an embedding for the input word and an embedding of a binary variable which is 1 for the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

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