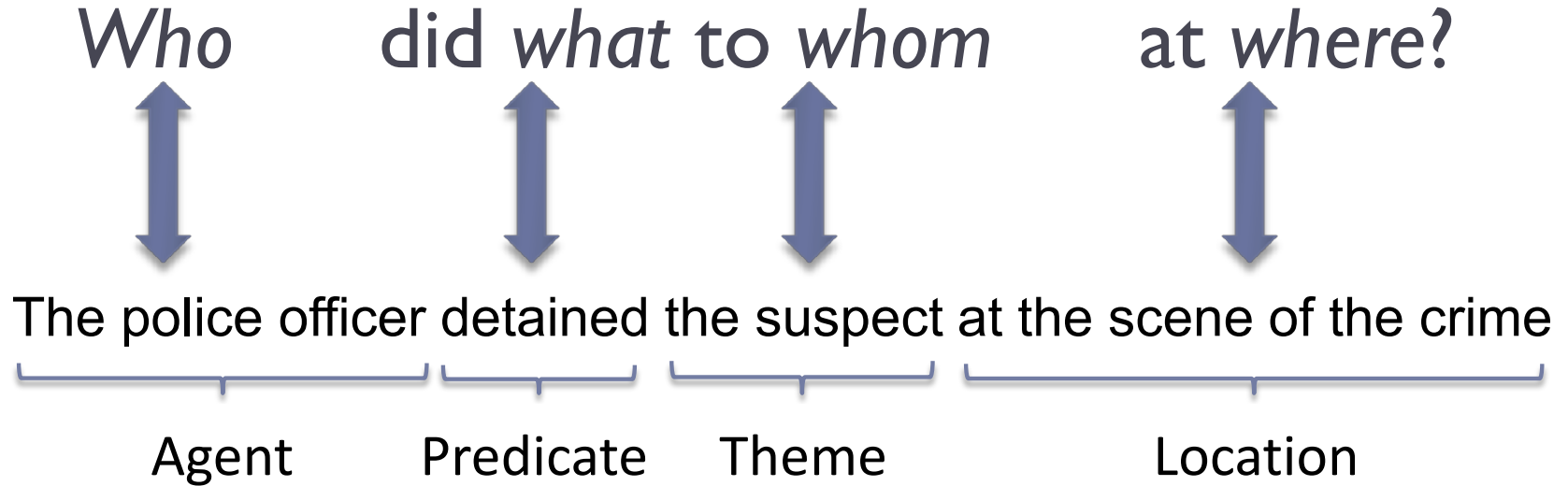


# Semantic Role Labeling

## Introduction

Many slides adapted from Dan Jurafsky

# Semantic Role Labeling



Can we figure out that these have the same meaning?

XYZ corporation **bought** the stock.

They **sold** the stock to XYZ corporation.

The stock was **bought** by XYZ corporation.

The **purchase** of the stock by XYZ corporation...

The stock **purchase** by XYZ corporation...



# Semantic Role Labeling

Semantic Roles

# Getting to semantic roles

Neo-Davidsonian event representation:

Sasha broke the window

$$\exists e, x, y \text{ Breaking}(e) \wedge \text{Breaker}(e, \text{Sasha}) \\ \wedge \text{BrokenThing}(e, y) \wedge \text{Window}(y)$$

Pat opened the door

$$\exists e, x, y \text{ Opening}(e) \wedge \text{Opener}(e, \text{Pat}) \\ \wedge \text{OpenedThing}(e, y) \wedge \text{Door}(y)$$

Subjects of break and open: **Breaker** and **Opener**

**Deep roles** specific to each event (breaking, opening)

Hard to reason about them for NLU applications like QA

# Thematic roles

- **Breaker** and **Opener** have something in common!
  - Volitional actors
  - Often animate
  - Direct causal responsibility for their events
- Thematic roles are a way to capture this semantic commonality between *Breakers* and *Eaters*.
- They are both AGENTS.
- The *BrokenThing* and *OpenedThing*, are THEMES.
  - prototypically inanimate objects affected in some way by the action

# Thematic roles

- One of the oldest linguistic models
  - Indian grammarian Panini between the 7th and 4th centuries BCE
- Modern formulation from Fillmore (1966,1968), Gruber (1965)
  - Fillmore influenced by Lucien Tesnière's (1959) *Éléments de Syntaxe Structurale*, the book that introduced dependency grammar
  - Fillmore first referred to roles as *actants* (Fillmore, 1966) but switched to the term *case*



# Thematic roles

- A typical set:

Thematic Role	Definition	Example
AGENT	The volitional causer of an event	<i>The waiter</i> spilled the soup.
EXPERIENCER	The experiencer of an event	<i>John</i> has a headache.
FORCE	The non-volitional causer of the event	<i>The wind</i> blows debris from the mall into our yards.
THEME	The participant most directly affected by an event	Only after Benjamin Franklin broke <i>the ice</i> ...
RESULT	The end product of an event	The city built a <i>regulation-size baseball diamond</i> ...
CONTENT	The proposition or content of a propositional event	Mona asked “ <i>You met Mary Ann at a supermarket?</i> ”
INSTRUMENT	An instrument used in an event	He poached catfish, stunning them <i>with a shocking device</i> ...
BENEFICIARY	The beneficiary of an event	Whenever Ann Callahan makes hotel reservations <i>for her boss</i> ...
SOURCE	The origin of the object of a transfer event	I flew in <i>from Boston</i> .
GOAL	The destination of an object of a transfer event	I drove <i>to Portland</i> .



# Diathesis alternations (or verb alternation)

*Doris gave the book to Cary.*

AGENT            THEME            BENEFICIARY

*Break:* AGENT, INSTRUMENT, or THEME as subject

*Doris gave Cary the book.*

AGENT BENEFICIARY THEME

*Give:* THEME and BENEFICIARY in either order

**Dative alternation:** particular semantic classes of verbs, “verbs of future having” (*advance, allocate, offer, owe*), “send verbs” (*forward, hand, mail*), “verbs of throwing” (*kick, pass, throw*), etc.

**Levin (1993):** 47 semantic classes (“**Levin classes**”) for 3100 English verbs and alternations. In online resource VerbNet.

# Problems with Thematic Roles

Hard to create standard set of roles or formally define them  
Often roles need to be fragmented to be defined.

Levin and Rappaport Hovav (2015): two kinds of INSTRUMENTS  
**intermediary instruments** that can appear as subjects

The cook opened the jar with the new gadget.

The new gadget opened the jar.

**enabling instruments** that cannot

Shelly ate the sliced banana with a fork.

\*The fork ate the sliced banana.

# Alternatives to thematic roles

- 1. Fewer roles:** generalized semantic roles, defined as prototypes (Dowty 1991)  
PROTO-AGENT  
PROTO-PATIENT  
[PropBank](#)
- 2. More roles:** Define roles specific to a group of predicates  
[FrameNet](#)

# Semantic Role Labeling

The Proposition Bank  
(PropBank)

# PropBank

- Palmer, Martha, Daniel Gildea, and Paul Kingsbury. 2005. The Proposition Bank: An Annotated Corpus of Semantic Roles. *Computational Linguistics*, 31(1):71–106

# PropBank Roles

Following Dowty 1991

## Proto-Agent

- Volitional involvement in event or state
- Sentience (and/or perception)
- Causes an event or change of state in another participant
- Movement (relative to position of another participant)

## Proto-Patient

- Undergoes change of state
- Causally affected by another participant
- Stationary relative to movement of another participant



# PropBank Roles

- Following Dowty 1991
  - Role definitions determined verb by verb, with respect to the other roles
  - Semantic roles in PropBank are thus verb-sense specific.
- Each verb sense has numbered argument: Arg0, Arg1, Arg2,...

Arg0: PROTO-AGENT

Arg1: PROTO-PATIENT

Arg2: usually: benefactive, instrument, attribute, or end state

Arg3: usually: start point, benefactive, instrument, or attribute

Arg4 the end point

17 *(Arg2-Arg5 are not really that consistent, causes a problem for labeling)*

# PropBank Frame Files

## agree.01

Arg0: Agreeer

Arg1: Proposition

Arg2: Other entity agreeing

Ex1: [Arg0 The group] *agreed* [Arg1 it wouldn't make an offer].

Ex2: [ArgM-TMP Usually] [Arg0 John] *agrees* [Arg2 with Mary]  
[Arg1 on everything].

## fall.01

Arg1: Logical subject, patient, thing falling

Arg2: Extent, amount fallen

Arg3: start point

Arg4: end point, end state of arg1

Ex1: [Arg1 Sales] *fell* [Arg4 to \$25 million] [Arg3 from \$27 million].

Ex2: [Arg1 The average junk bond] *fell* [Arg2 by 4.2%].

# Advantage of a ProbBank Labeling

**increase.01** “go up incrementally”

Arg0: causer of increase

Arg1: thing increasing

Arg2: amount increased by, EXT, or MNR

Arg3: start point

Arg4: end point

This would allow us to see the commonalities in these 3 sentences:

[Arg0 Big Fruit Co. ] increased [Arg1 the price of bananas].

[Arg1 The price of bananas] was increased again [Arg0 by Big Fruit Co. ]

[Arg1 The price of bananas] increased [Arg2 5%].

# Modifiers or adjuncts of the predicate:

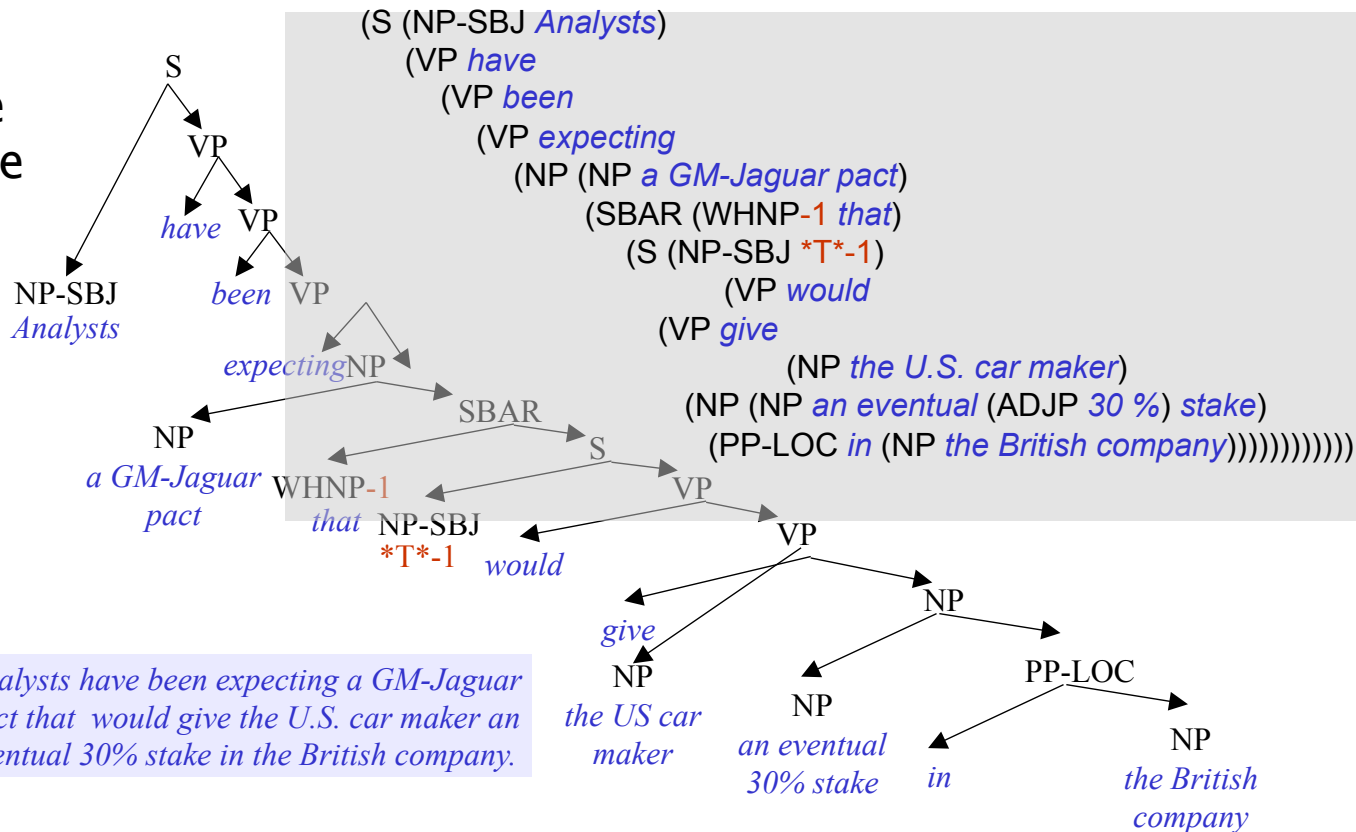
## Arg-M

<b>ArgM-TMP</b>	when?	yesterday evening, now
<b>LOC</b>	where?	at the museum, in San Francisco
<b>DIR</b>	where to/from?	down, to Bangkok
<b>MNR</b>	how?	clearly, with much enthusiasm
<b>PRP/CAU</b>	why?	because ... , in response to the ruling
<b>REC</b>		themselves, each other
<b>ADV</b>	miscellaneous	
<b>PRD</b>	secondary predication	...ate the meat raw

# PropBanking a Sentence

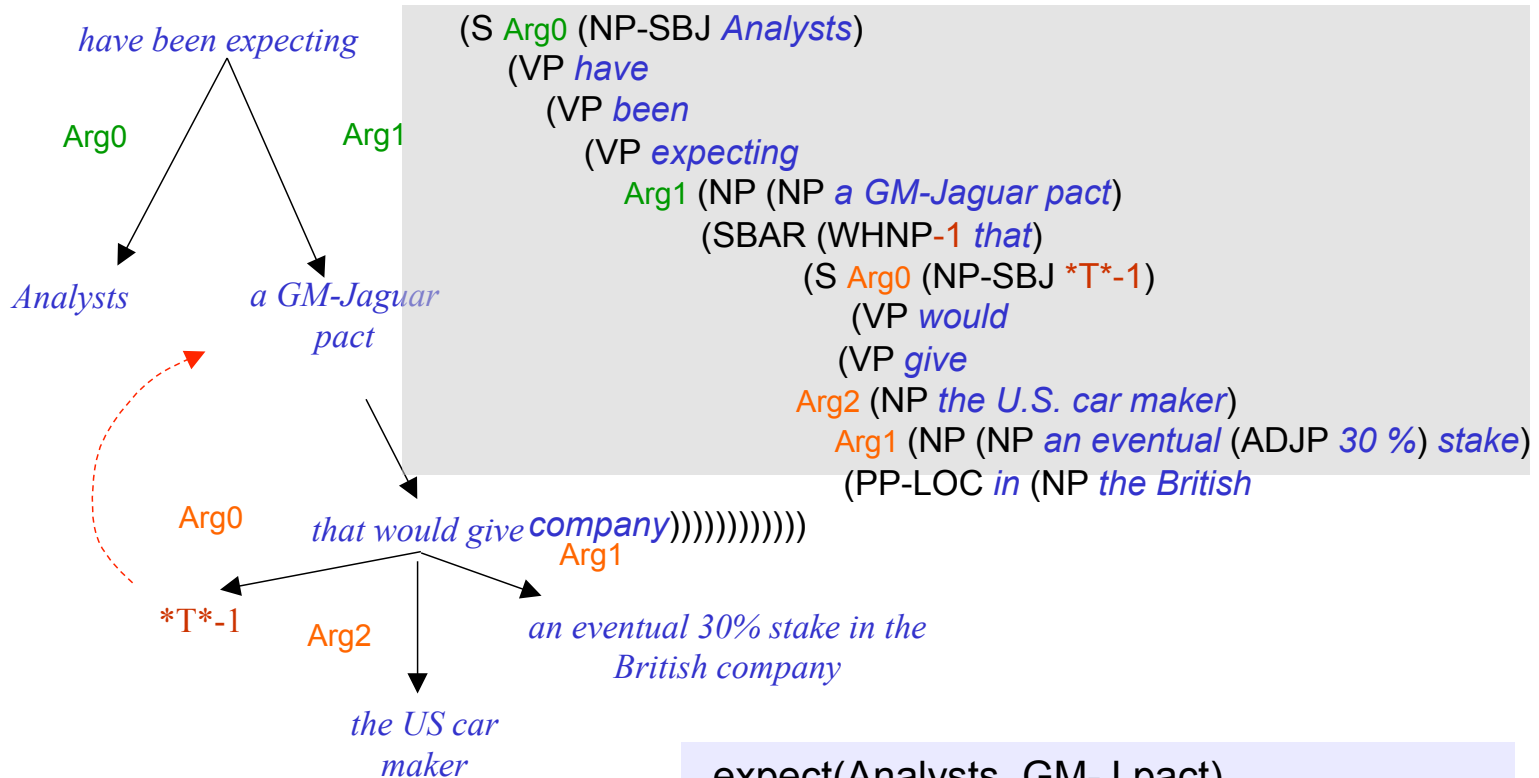
Martha Palmer 2013

A sample  
parse tree



# The same parse tree PropBanked

Martha Palmer 2013



expect(Analysts, GM-J pact)  
give(GM-J pact, US car maker, 30% stake)

# Annotated PropBank Data

- Penn English TreeBank, OntoNotes 5.0.
  - Total ~2 million words
- Penn Chinese TreeBank
- Hindi/Urdu PropBank
- Arabic PropBank

2013 Verb Frames Coverage  
Count of word sense (lexical units)

<i><b>Language</b></i>	<i><b>Final Count</b></i>
<b>English</b>	<b>10,615*</b>
<b>Chinese</b>	<b>24,642</b>
<b>Arabic</b>	<b>7,015</b>

# Plus nouns and light verbs

Example Noun: *Decision*

▶ Roleset: Arg0: decider, Arg1: decision...

▶ “[...**[your<sub>ARG0</sub>]** **[decision<sub>REL</sub>]**  
**[to say look I don't want to go through this anymore<sub>ARG1</sub>]**”

Example within an LVC: *Make a decision*

▶ “[...**[the President<sub>ARG0</sub>]** **[made<sub>REL-LVB</sub>]**  
the **[fundamentally correct<sub>ARGM-ADJ</sub>]**  
**[decision<sub>REL</sub>]** **[to get on offense<sub>ARG1</sub>]**”



# Semantic Role Labeling

Semantic Role Labeling  
Algorithm

# Semantic role labeling (SRL)

- The task of finding the semantic roles of each argument of each predicate in a sentence.
- FrameNet versus PropBank:

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

[The San Francisco Examiner] issued [a special edition] [yesterday]  
ARG0                            TARGET ARG1                            ARGM-TMP

# History

- Semantic roles as a intermediate semantics, used early in
  - machine translation (Wilks, 1973)
  - question-answering (Hendrix et al., 1973)
  - spoken-language understanding (Nash-Webber, 1975)
  - dialogue systems (Bobrow et al., 1977)
- Early SRL systems
  - Simmons 1973, Marcus 1980:
    - parser followed by hand-written rules for each verb
    - dictionaries with verb-specific case frames (Levin 1977)

# Why Semantic Role Labeling

- A useful shallow semantic representation
- Improves NLP tasks like:
  - question answering  
Shen and Lapata 2007, Surdeanu et al. 2011
  - machine translation  
Liu and Gildea 2010, Lo et al. 2013

# A simple modern algorithm

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

```
  parse ← PARSE(words)
```

```
  for each predicate in parse do
```

```
    for each node in parse do
```

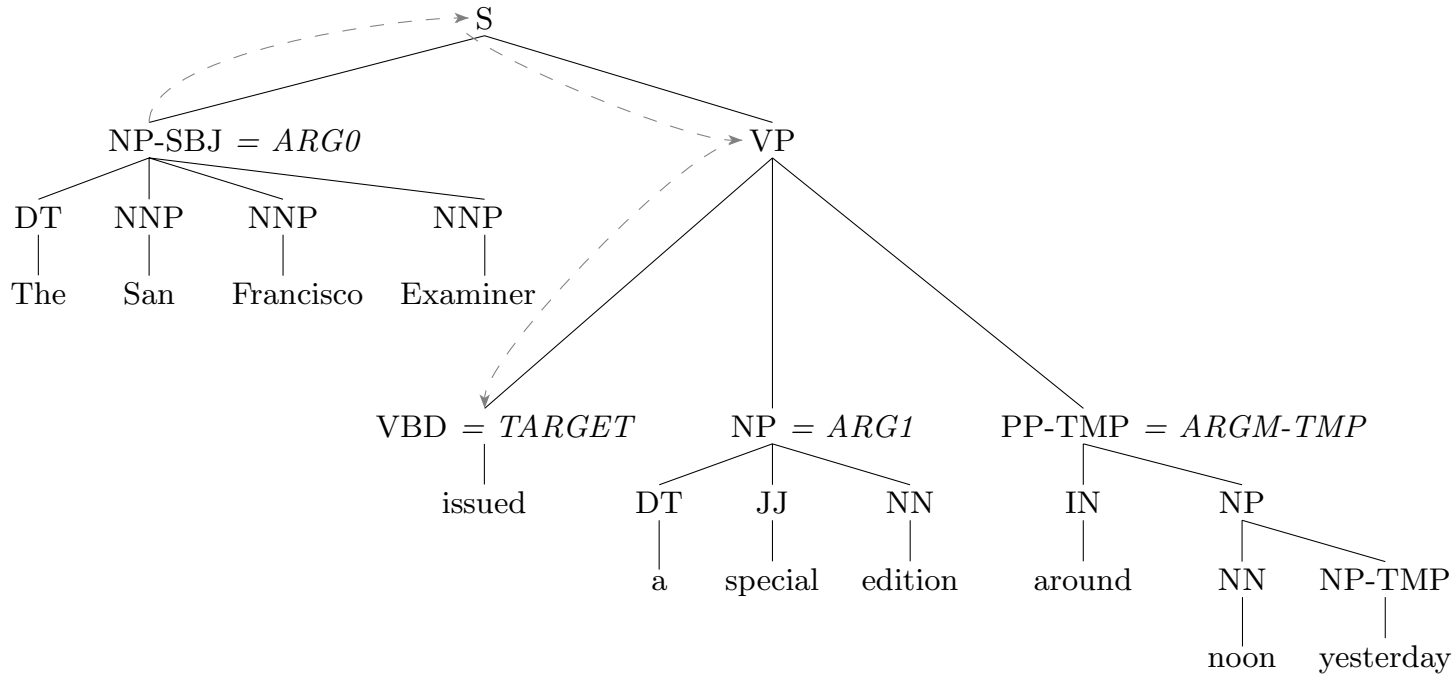
```
      featurevector ← EXTRACTFEATURES(node, predicate, parse)
```

```
      CLASSIFYNODE(node, featurevector, parse)
```

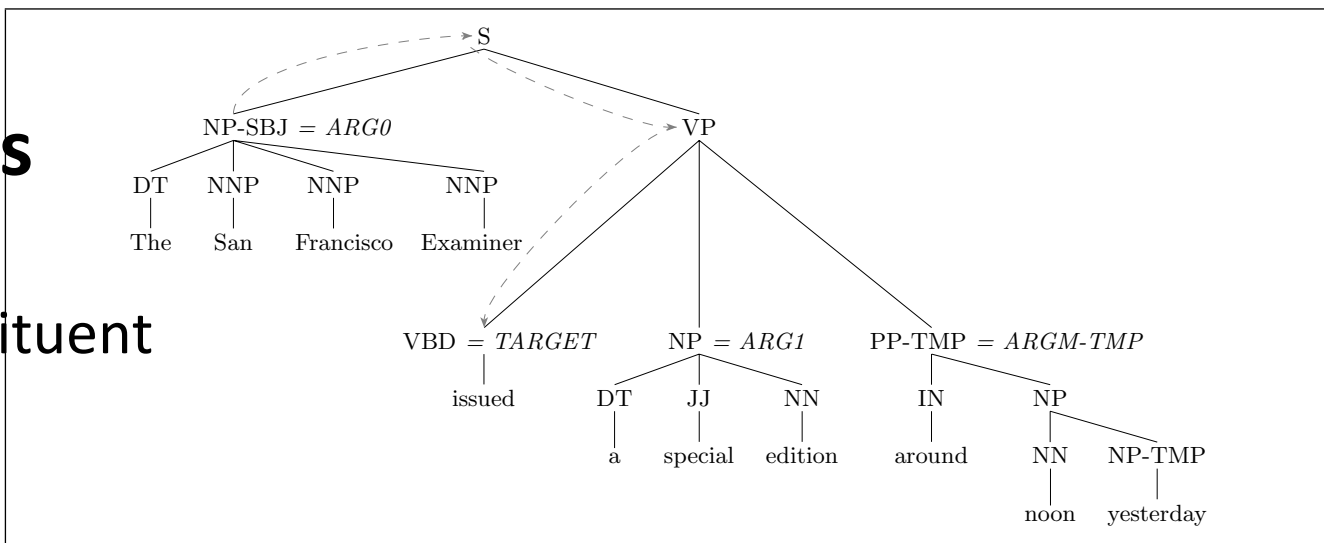
# How do we decide what is a predicate

- If we're just doing PropBank verbs
  - Choose all verbs
  - Possibly removing light verbs (from a list)
- If we're doing FrameNet (verbs, nouns, adjectives)
  - Choose every word that was labeled as a target in training data

# Semantic Role Labeling



# Features



Headword of constituent

Examiner

Headword POS

NNP

Voice of the clause

Active

Subcategorization of pred

VP -> VBD NP PP

Named Entity type of constit

ORGANIZATION

First and last words of constit

The, Examiner

Linear position, clause re: predicate

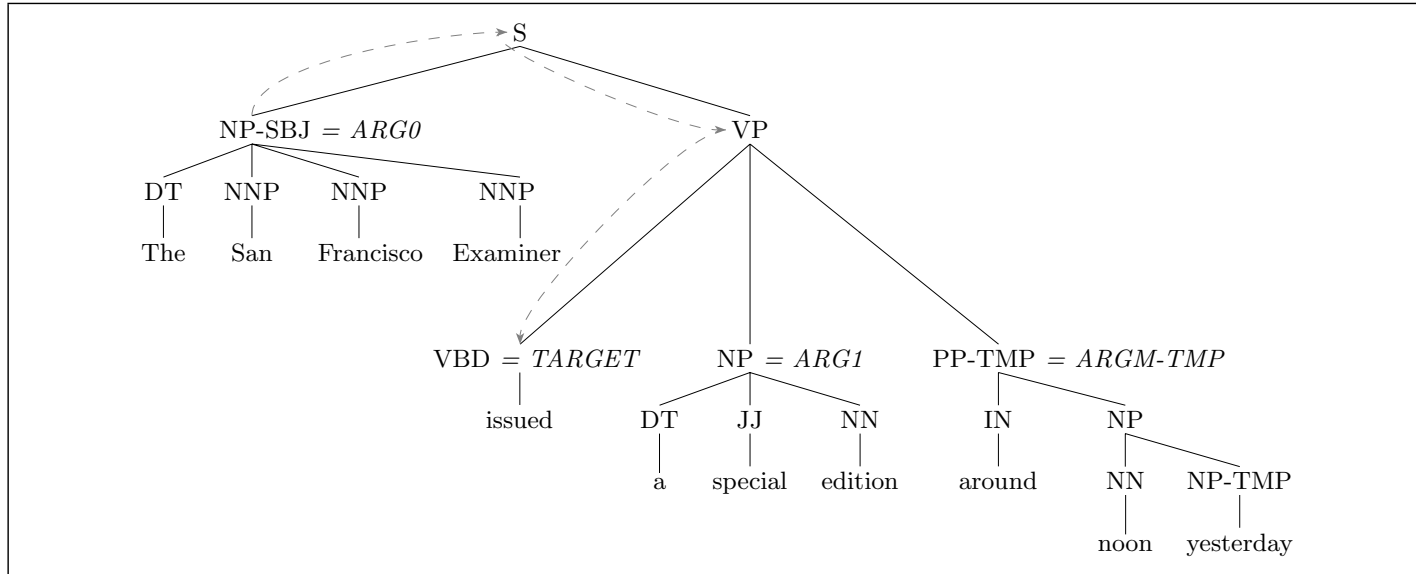
before



# Path Features

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

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



# Final feature vector

- For “The San Francisco Examiner”,
- Arg0, [issued, NP, Examiner, NNP, active, before, VP→VBD NP PP, ORG, The, Examiner, NP↑S↓VP↓VBD]
- Other features could be used as well
  - sets of n-grams inside the constituent
  - other path features
    - the upward or downward halves
    - whether particular nodes occur in the path

## 3-step version of SRL algorithm

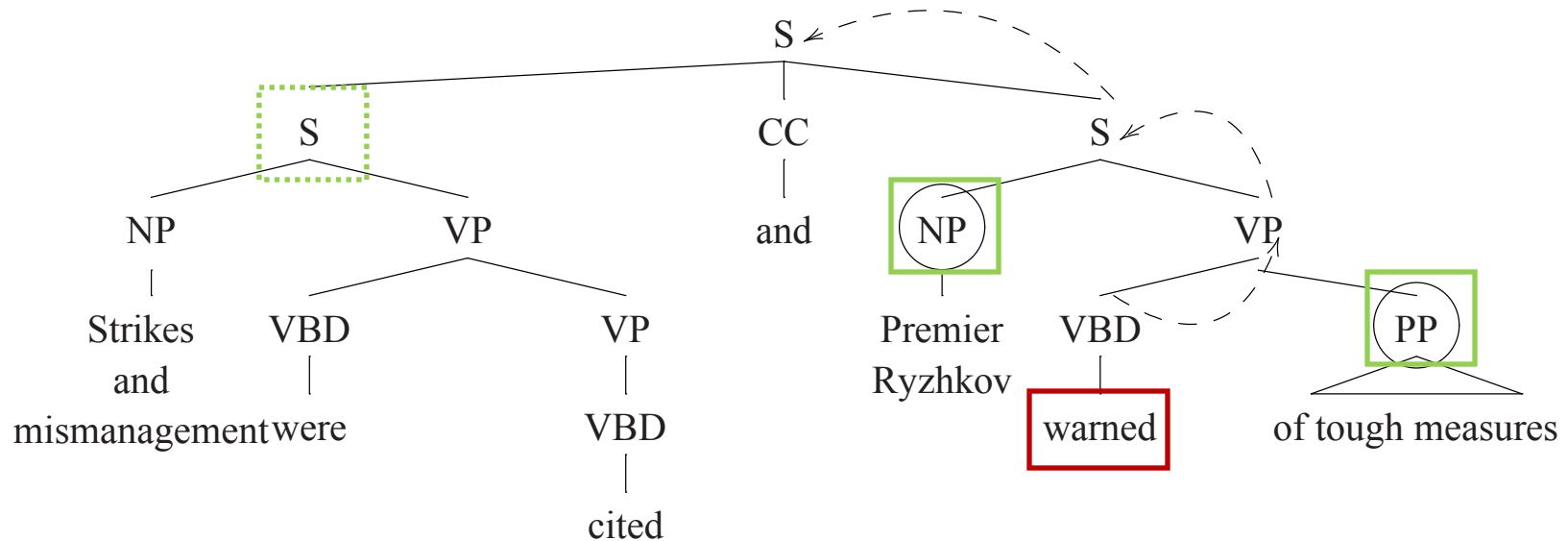
- 1. Pruning:** use simple heuristics to prune unlikely constituents.
- 2. Identification:** a binary classification of each node as an argument to be labeled or a NONE.
- 3. Classification:** a 1-of- $N$  classification of all the constituents that were labeled as arguments by the previous stage

# Why add Pruning and Identification steps?

- Algorithm is looking at one predicate at a time
- Very few of the nodes in the tree could possibly be arguments of that one predicate
- Imbalance between
  - positive samples (constituents that are arguments of predicate)
  - negative samples (constituents that are not arguments of predicate)
- Imbalanced data can be hard for many classifiers
- So we prune the **very** unlikely constituents first, and then use a classifier to get rid of the rest.

# Pruning heuristics – Xue and Palmer (2004)

- Add sisters of the predicate, then aunts, then great-aunts, etc
  - But ignoring anything in a coordination structure



# A common final stage: joint inference

- The algorithm so far classifies everything **locally** – each decision about a constituent is made independently of all others
- But this can't be right: Lots of **global** or **joint** interactions between arguments
  - Constituents in FrameNet and PropBank must be non-overlapping.
    - A local system may incorrectly label two overlapping constituents as arguments
    - PropBank does not allow multiple identical arguments
      - labeling one constituent ARG0
      - Thus should increase the probability of another being ARG1

# How to do joint inference

- Reranking
  - The first stage SRL system produces multiple possible labels for each constituent
  - The second stage classifier the best **global** label for all constituents
  - Often a classifier that takes all the inputs along with other features (sequences of labels)

# Semantic Role Labeling

Conclusion



# Semantic Role Labeling

- A level of shallow semantics for representing events and their participants
  - Intermediate between parses and full semantics
- Two common architectures, for various languages
  - FrameNet: frame-specific roles
  - PropBank: Proto-roles
- Current systems extract by
  - parsing sentence
  - Finding predicates in the sentence
    - For each one, classify each parse tree constituent