Semantic Role Labeling

Introduction

Many slides adapted from Dan Jurafsky

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

Who did *what* to *whom* at *where?*

The police officer detained the suspect at the scene of the crime

Agent Predicate Theme Location

A Shallow Semantic Representation: Semantic Roles

Predicates (bought, sold, purchase) represent an **event**

semantic roles express the abstract role that arguments of a predicate can take in the event

More specific ⟷ More general

buyer **agent** **agent**

Semantic Role Labeling

Semantic Roles

Getting to semantic roles

Neo-Davidsonian event representation:

Sasha broke the window

Pat opened the door

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

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

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

Thematic grid, case frame, θ-grid

Example usages of "break"

John *broke the window.*
AGENT THEME

John *broke the window with a rock.*
AGENT THEME INSTRUMENT

The rock *broke the window.*
INSTRUMENT THEME

The window broke.
THEME

The window was broken by John.
THEME AGENT

thematic grid, case frame, θ-grid
Break:
AGENT, THEME, INSTRUMENT.

Some realizations:

AGENT/Subject, THEME/Object
AGENT/Subject, THEME/Object, INSTRUMENT/PP_{with}
INSTRUMENT/Subject, THEME/Object
THEME/Subject

Diathesis alternations (or verb alternation)

Doris gave the book to Cary.
AGENT THEME BENEFICIARY

Doris gave Cary the book.
AGENT BENEFICIARY THEME

Break: AGENT, INSTRUMENT, or THEME as subject

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.

Semantic Role Labeling

The Proposition Bank (PropBank)

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

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

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

PropBank Frame Files

agree.01

Arg0: Agreer
Arg1: Proposition
Arg2: Other entity agreeing

Ex1: [$_{\text{Arg0}}$ The group] *agreed* [$_{\text{Arg1}}$ it wouldn't make an offer].
Ex2: [$_{\text{ArgM-TMP}}$ Usually] [$_{\text{Arg0}}$ John] *agrees* [$_{\text{Arg2}}$ with Mary] [$_{\text{Arg1}}$ 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: [$_{\text{Arg1}}$ Sales] *fell* [$_{\text{Arg4}}$ to \$25 million] [$_{\text{Arg3}}$ from \$27 million].
Ex2: [$_{\text{Arg1}}$ The average junk bond] *fell* [$_{\text{Arg2}}$ by 4.2%].

Modifiers or adjuncts of the predicate: Arg-M

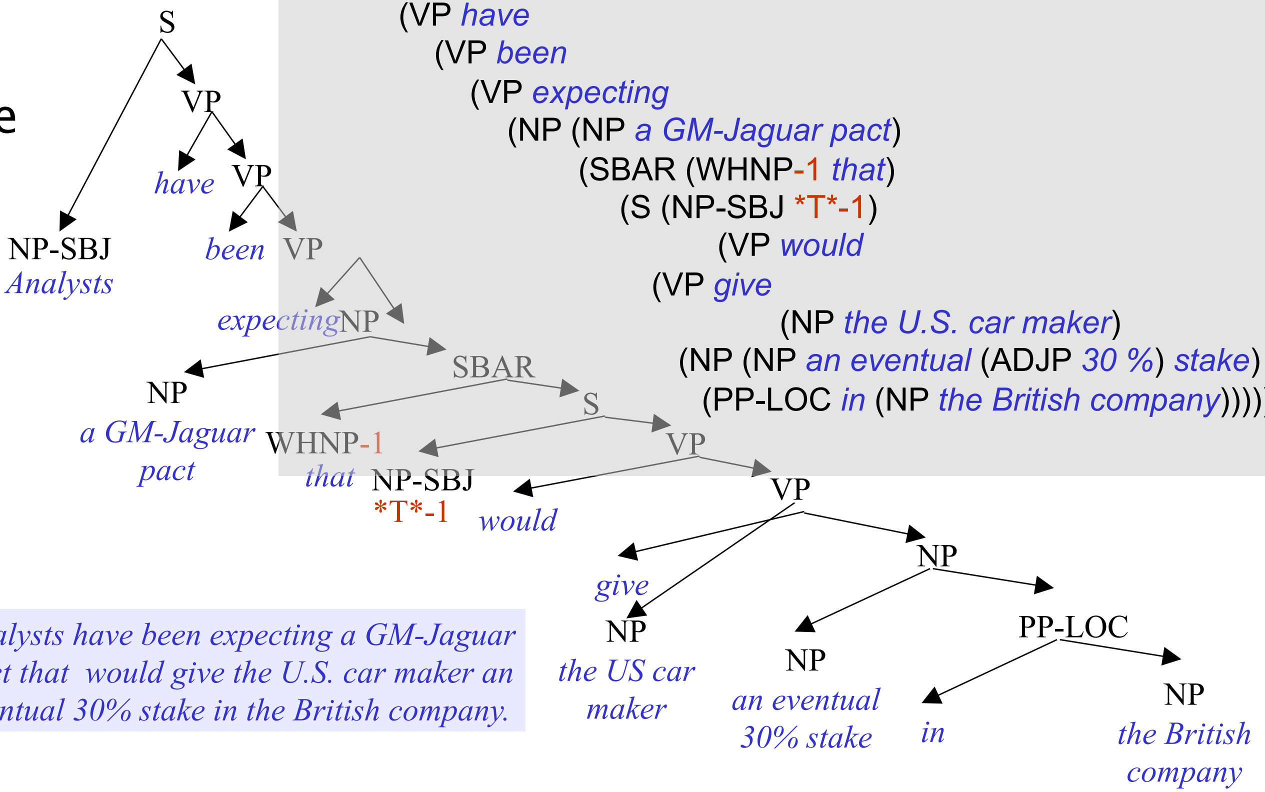
ArgM-TMP	when?	yesterday evening, now
LOC	where?	at the museum, in San Francisco
DIR	where to/from?	down, to Bangkok
MNR	how?	clearly, with much enthusiasm
PRP/CAU	why?	because ... , in response to the ruling
REC		themselves, each other
ADV	miscellaneous	
PRD	secondary predication	...ate the meat raw

PropBanking a Sentence

Martha Palmer 2013

A sample parse tree

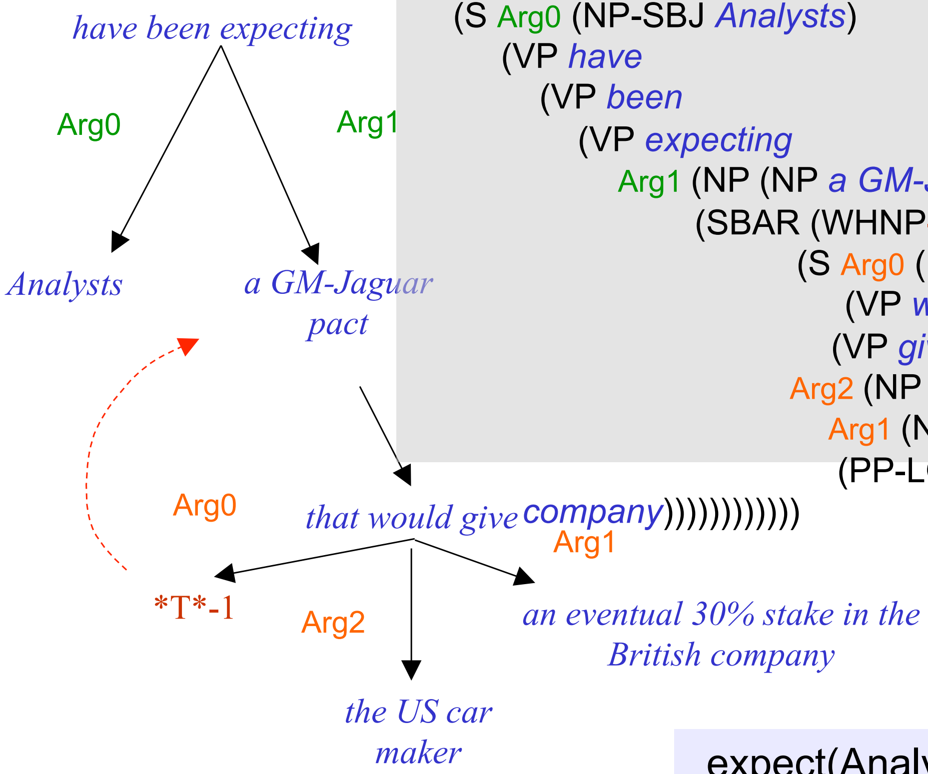
```
(S (NP-SBJ Analysts)
   (VP have
      (VP been
         (VP expecting
            (NP (NP a GM-Jaguar pact)
                (SBAR (WHNP-1 that)
                   (S (NP-SBJ *T*-1)
                      (VP would
         (VP give
                  (NP the U.S. car maker)
              (NP (NP an eventual (ADJP 30 %) stake)
                 (PP-LOC in (NP the British company))))))))))))
```



Analysts have been expecting a GM-Jaguar pact that would give the U.S. car maker an eventual 30% stake in the British company.

The same parse tree PropBanked

Martha Palmer 2013



(S Arg0 (NP-SBJ *Analysts*)
(VP *have*
(VP *been*
(VP *expecting*
Arg1 (NP (NP *a GM-Jaguar pact*)
(SBAR (WHNP-1 *that*)
(S Arg0 (NP-SBJ *T*-1)
(VP *would*
(VP *give*
Arg2 (NP *the U.S. car maker*)
Arg1 (NP (NP *an eventual* (ADJP *30 %*) *stake*)
(PP-LOC *in* (NP *the British*
company))))))))))))

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

Annotated PropBank Data

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

Language	*Final Count*
English	**10,615***
Chinese	**24, 642**
Arabic	**7,015**

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

From Martha Palmer 2013 Tutorial

Plus nouns and light verbs

Example Noun: *Decision*

- Roleset: Arg0: decider, Arg1: decision…

- "…[your$_{ARG0}$] [decision$_{REL}$] [to say look I don't want to go through this anymore$_{ARG1}$]"

Example within an LVC: *Make a decision*

- "…[the President$_{ARG0}$] [made$_{REL-LVB}$] the [fundamentally correct$_{ARGM-ADJ}$] [decision$_{REL}$] [to get on offense$_{ARG1}$]"

Slight from Palmer 2013

Semantic Role Labeling

Semantic Role Labeling Algorithm

Semantic Role Labeling

Who did *what* to *whom* at *where?*

The police officer detained the suspect at the scene of the crime

Agent Predicate Theme Location

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

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)

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

A simple modern algorithm

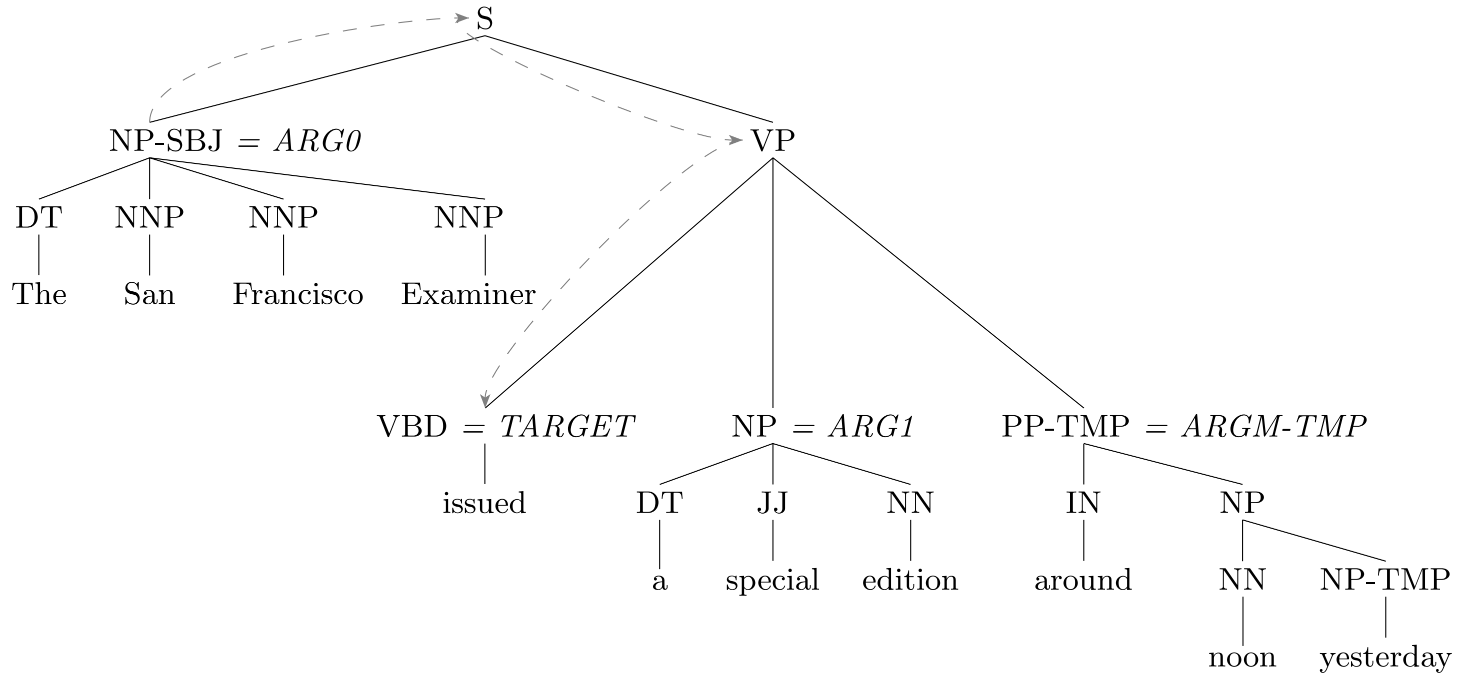
function SEMANTICROLELABEL(*words*) **returns** labeled tree

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

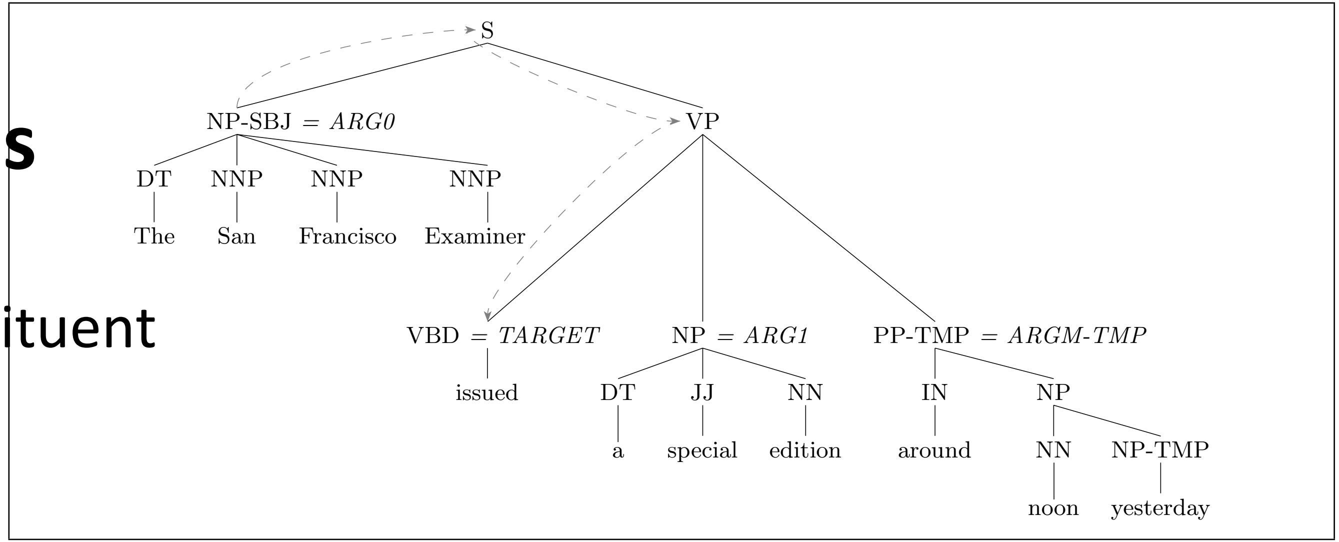
How do we decide what is a predicate

- 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

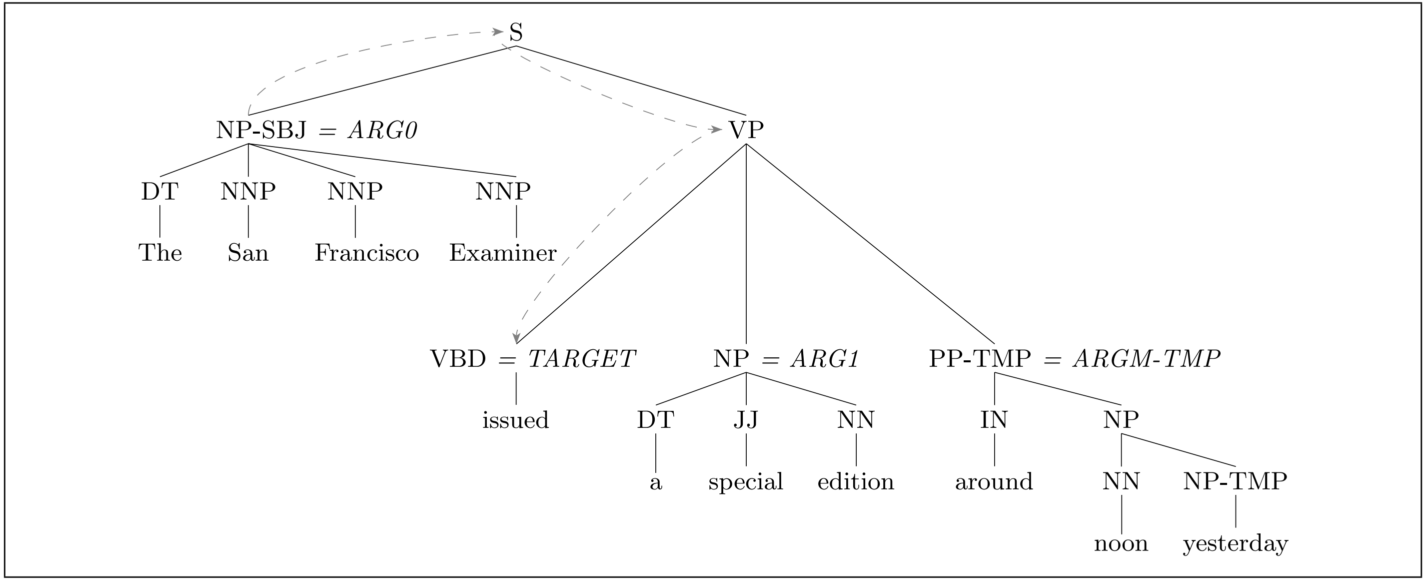
Linear position,clause re: predicate

before

Path Features

Path in the parse tree from the constituent to the predicate

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



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