

Semantics: Roles and Relations

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CS 295: STATISTICAL NLP

WINTER 2017

February 14, 2017

Outline

Structured Perceptron

Word Senses

Semantic Roles

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Structured Perceptron

Word Senses

Semantic Roles

Structured Prediction

Log-linear model

$$y \in \mathcal{L}$$

$$f(\vec{x}) = \operatorname{argmax}_{y \in \mathcal{L}}$$

$$\frac{e^{\theta \cdot \phi(\vec{x}, y)}}{\sum_y e^{\theta \cdot \phi(\vec{x}, y)}}$$

$\vec{y} \in \mathcal{Y}$
set of seq
set of trees
 $y_1 \dots y_n$

$$f(\vec{x}) = \operatorname{argmax}_{y \in \mathcal{Y}}$$

$$\frac{e^{\theta \cdot \phi(\vec{x}, \vec{y})}}{\sum_{\vec{y}} e^{\theta \cdot \phi(\vec{x}, \vec{y})}}$$

Likelihood Learning

$$\begin{aligned}
 \mathcal{L}(\{\vec{x}_i, \vec{y}_i\}, \theta) &= \log \prod_i P(y_i | x_i) = \sum_i \theta \cdot \phi(\vec{x}_i, \vec{y}_i) - \log \sum_y e^{\theta \cdot \phi(\vec{x}_i, \vec{y})} \\
 &= \sum_i \theta \cdot \phi(\vec{x}_i, \vec{y}_i) - \underbrace{\log \sum_y e^{\theta \cdot \phi(\vec{x}_i, \vec{y})}}_{\text{log Partition}}
 \end{aligned}$$

$$\frac{\partial \mathcal{L}}{\partial \theta_k} = \sum_i \underbrace{\phi_k(\vec{x}_i, \vec{y}_i)}_{\text{feature counts in the data}} - \sum_y \underbrace{P(y | \vec{x}_i) \phi_k(\vec{x}_i, \vec{y})}_{\text{exp feat counts acc. to } \theta}$$

Perceptron Algorithm

$$\theta_0 \leftarrow [0 \dots 0]$$

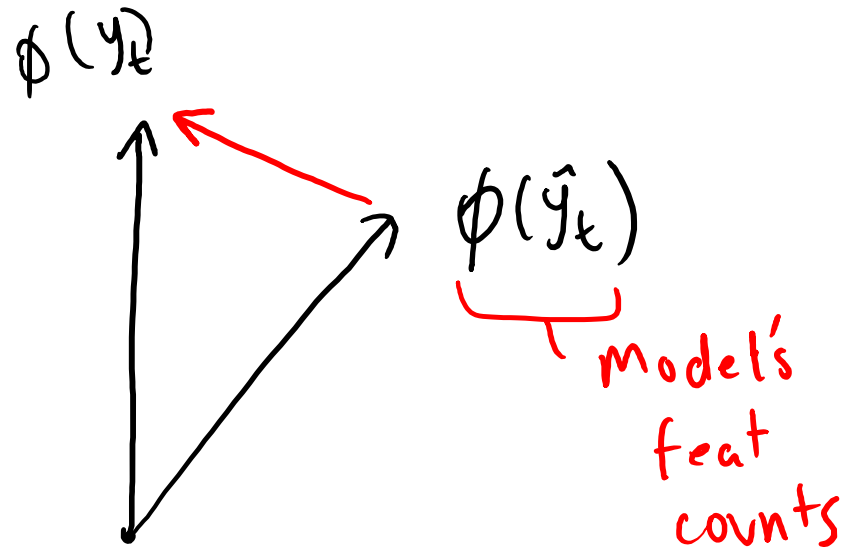
pick random (x_t, y_t) :

$$\hat{y}_t = \underset{y}{\operatorname{argmax}} \theta \cdot \phi(\vec{x}_t, y)$$

$$\theta_t \leftarrow \theta_{t-1} + (\phi(x_t, y_t) - \phi(x_t, \hat{y}_t))$$

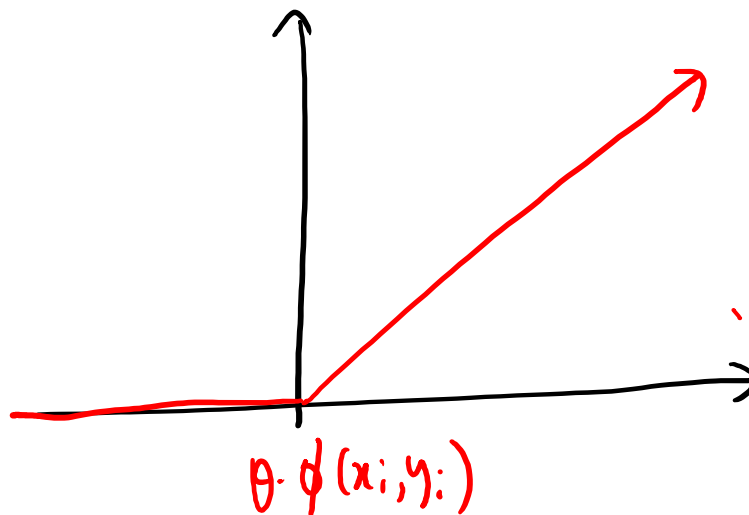
return θ_T

Structured Perceptron



Structured Hinge Loss

$$\mathcal{L}(\{x_i, y_i\}, \theta) = \sum_i \theta \cdot \phi(x_i, y_i) - \arg\max_y \theta \cdot \phi(x_i, y)$$

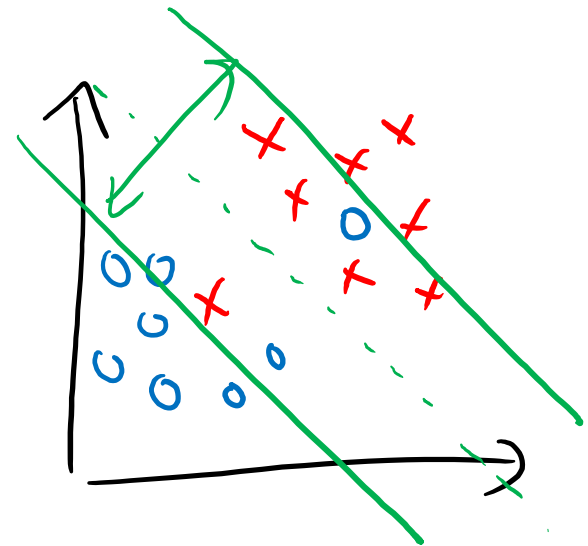


Weight Averaging

$$\theta_t \leftarrow \theta_{t-1} + \phi(x, y_t) - \phi(x, \hat{y}_t)$$

$$\theta_T$$

$$\sum_t \frac{\theta_t}{T}$$



Outline

Structured Perceptron

Word Senses

Semantic Roles

Words and Senses

Instead, a **bank** can hold the investments in a custodial account in the client's name.

But as agriculture burgeons on the east **bank**, the river will shrink even more.

Senses

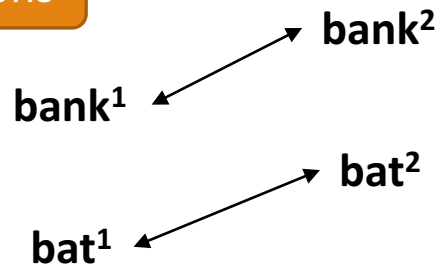
- bank¹: financial institution
- bank²: sloping mound

Each word can have many senses..
Most non-rare words in English do.

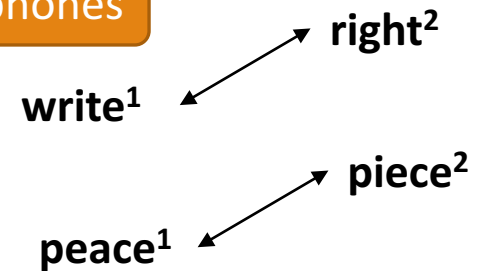
Homonymy

Same *form*, completely different meanings...

Homographs



Homophones



Applications

Information Retrieval

- “bat care”

Machine Translation

- Bat: murcielago or bate?

Text to Speech

- “bass” (fish) or “bass” (guitar)

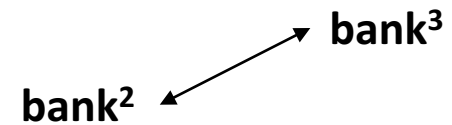
Speech to Text

- “piece” or “peace”

Polysemy

The **bank** was constructed in 1875 out of local brick.
I withdrew the money from the **bank**.

Same form, but very related meanings...



Metonymy

Systemic relationship between senses.

Building ↔ Organization school, university, hospital

Author ↔ Works of the Author Jane Austen wrote Emma
I love Jane Austen!

Tree ↔ Fruit Plums have beautiful blossoms
I ate a preserved plum

Multiple senses or not?

Which flights **serve** breakfast?
Does Lufthansa **serve** Philadelphia?

“Zeugma” Test

Does Lufthansa **serve** breakfast and San Jose?

Sounds weird, so there are multiple senses of “serve”.

You are free to execute your laws,
and your citizens, as you see fit.

Riker, Star Trek: The Next Generation



How do we define the sense?

Dictionary

right *adj.* located nearer the right hand esp. being on the right when facing the same direction as the observer.

left *adj.* located nearer to this side of the body than the right.

red *n.* the color of blood or a ruby.

blood *n.* the red liquid that circulates in the heart, arteries and veins of animals.

Define senses in relation to other senses!

Synonyms

Substitute one for the other in **any** sentence.

Perfect synonymy, doesn't exist

Many things define acceptability: *politeness, slang, register, genre*

Substitute one for the other in **most** sentence.

couch / sofa

big / large

automobile / car

vomit¹ / throw up³

water¹ / H₂O²

Synonymy is between sense, not words

Antonyms

Sense that are opposite with respect to **one feature of meaning**..
otherwise very similar!

dark/light
hot/cold

short/long
up/down

fast/slow
in/out

rise/fall
big/little

Binary Opposition

Or at opposite ends of a scale

dark/light short/long fast/slow
hot/cold big/little

Reversives

Opposite directions or change

rise/fall up/down in/out

Hyponymy and Hypernymy

Hyponyms / Subordinate

One sense is a **hyponym** of another if the first sense is more specific, denoting a subclass of the other

car is a hyponym of *vehicle*
mango is a hyponym of *fruit*

Hypernyms / Superordinate

Conversely **hypernym** denotes one is a superclass of the other

vehicle is a hypernym of *car*
fruit is a hypernym of *mango*

WordNet

Category	Unique Strings
Noun	117,798
Verb	11,529
Adjective	22,479
Adverb	4,481

Noun

- **S: (n) bass** (the lowest part of the musical range)
- **S: (n) bass, bass part** (the lowest part in polyphonic music)
- **S: (n) bass, basso** (an adult male singer with the lowest voice)
- **S: (n) sea bass, bass** (the lean flesh of a saltwater fish of the family Serranidae)
- **S: (n) freshwater bass, bass** (any of various North American freshwater fish with lean flesh (especially of the genus Micropterus))
- **S: (n) bass, bass voice, basso** (the lowest adult male singing voice)
- **S: (n) bass** (the member with the lowest range of a family of musical instruments)
- **S: (n) bass** (nontechnical name for any of numerous edible marine and freshwater spiny-finned fishes)

Adjective

- **S: (adj) bass, deep** (having or denoting a low vocal or instrumental range) *"a deep voice"; "a bass voice is lower than a baritone voice"; "a bass clarinet"*

WordNet Hierarchy

- [S: \(n\) bass](#), [basso](#) (an adult male singer with the lowest voice)
 - [direct hypernym](#) / [inherited hypernym](#) / [sister term](#)
 - [S: \(n\) singer](#), [vocalist](#), [vocalizer](#), [vocaliser](#) (a person who sings)
 - [S: \(n\) musician](#), [instrumentalist](#), [player](#) (someone who plays a musical instrument (as a profession))
 - [S: \(n\) performer](#), [performing artist](#) (an entertainer who performs a dramatic or musical work for an audience)
 - [S: \(n\) entertainer](#) (a person who tries to please or amuse)
 - [S: \(n\) person](#), [individual](#), [someone](#), [somebody](#), [mortal](#), [soul](#) (a human being) *"there was too much for one person to do"*
 - [S: \(n\) organism](#), [being](#) (a living thing that has (or can develop) the ability to act or function independently)
 - [S: \(n\) living thing](#), [animate thing](#) (a living (or once living) entity)
 - [S: \(n\) whole](#), [unit](#) (an assemblage of parts that is regarded as a single entity) *"how big is that part compared to the whole?"*; *"the team is a unit"*
 - [S: \(n\) object](#), [physical object](#) (a tangible and visible entity; an entity that can cast a shadow) *"it was full of rackets, balls and other objects"*
 - [S: \(n\) physical entity](#) (an entity that has physical existence)
 - [S: \(n\) entity](#) (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

Noun Relations

Relation	Also Called	Definition	Example
Hypernym	Superordinate	From concepts to superordinates	<i>breakfast</i> ¹ $\rightarrow$ <i>meal</i> ¹
Hyponym	Subordinate	From concepts to subtypes	<i>meal</i> ¹ $\rightarrow$ <i>lunch</i> ¹
Instance Hypernym	Instance	From instances to their concepts	<i>Austen</i> ¹ $\rightarrow$ <i>author</i> ¹
Instance Hyponym	Has-Instance	From concepts to concept instances	<i>composer</i> ¹ $\rightarrow$ <i>Bach</i> ¹
Member Meronym	Has-Member	From groups to their members	<i>faculty</i> ² $\rightarrow$ <i>professor</i> ¹
Member Holonym	Member-Of	From members to their groups	<i>copilot</i> ¹ $\rightarrow$ <i>crew</i> ¹
Part Meronym	Has-Part	From wholes to parts	<i>table</i> ² $\rightarrow$ <i>leg</i> ³
Part Holonym	Part-Of	From parts to wholes	<i>course</i> ⁷ $\rightarrow$ <i>meal</i> ¹
Substance Meronym		From substances to their subparts	<i>water</i> ¹ $\rightarrow$ <i>oxygen</i> ¹
Substance Holonym		From parts of substances to wholes	<i>gin</i> ¹ $\rightarrow$ <i>martini</i> ¹
Antonym		Semantic opposition between lemmas	<i>leader</i> ¹ $\iff$ <i>follower</i> ¹
Derivationally Related Form		Lemmas w/same morphological root	<i>destruction</i> ¹ $\iff$ <i>destroy</i> ¹

Verb Relations

Relation	Definition	Example
Hypernym	From events to superordinate events	$fly^9 \rightarrow travel^5$
Troponym	From events to subordinate event (often via specific manner)	$walk^1 \rightarrow stroll^1$
Entails	From verbs (events) to the verbs (events) they entail	$snore^1 \rightarrow sleep^1$
Antonym	Semantic opposition between lemmas	$increase^1 \iff decrease^1$
Derivationally Related Form	Lemmas with same morphological root	$destroy^1 \iff destruction^1$

Word Sense Disambiguation

The **bass** line of the song is too weak.

Noun

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Word Senses

Semantic Roles

Meaning is Subtle

I'm thrilled to visit sunny California.

I'm thrilled to visit California, where the weather is sunny.

I'm thrilled to visit California, where it's sunny.

I'm excited to visit California, where it's sunny.

I'm excited to visit California, where it's sunny out.

I'm excited to spend time in California, where it's sunny out.

I'm not excited to visit sunny California.

I'm thrilled to visit sunny Florida.

I'm thrilled to visit sunny Mountain View.

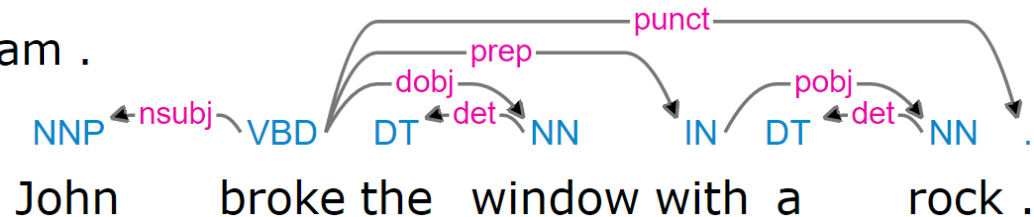
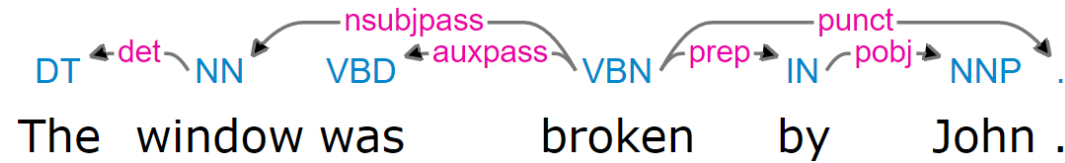
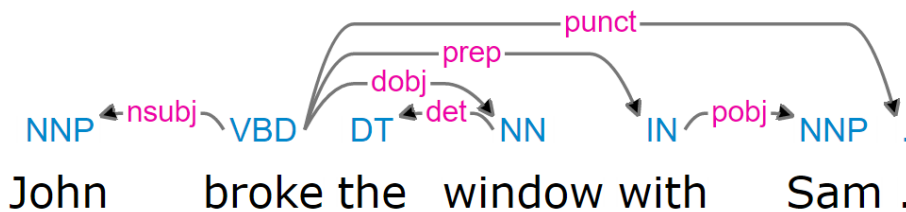
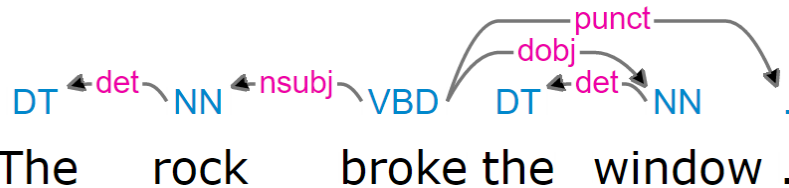
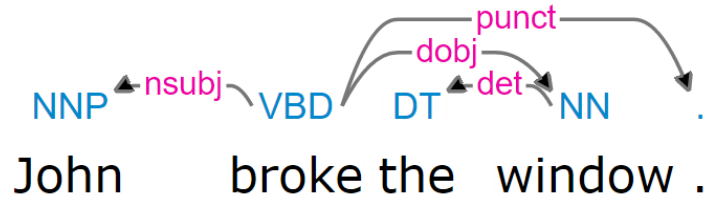
I'm thrilled to visit California because it's sunny.

I'm sort of happy about the California visit.

Verbs are key!

- Mary opened the door.
The door opened.
- John slices the bread with a knife.
The bread slices easily.
The knife slices easily.
- Mary loaded the truck with hay.
Mary loaded hay onto the truck.
The truck was loaded with hay (by Mary).
Hay was loaded onto the truck (by Mary).
- John got Mary a present.
John got a present for Mary.
Mary got a present from John.

Syntax ≠ Semantics



Need for “Roles”

The police officer **detained** the subject at the scene of the crime.

Who?	The police officer
Did what?	detained
To whom?	The subject
Where?	at the scene of the crime
When?	-

Thematic Roles

Agent	The waiter spilled the soup.
Experiencer	John has a headache.
Content	The wind blows debris into our yard.
Force	Jesse broke the window .
Instrument	The city built a regulation-sized baseball diamond .
Theme	Mona asked, " You met Mary Ann at the supermarket? "
Result	He poached catfish, stunning them with a shocking device .
Source	I flew in from Boston .
Beneficiary	Ann Callahan makes hotel reservations for her boss .
Goal	I drove to Portland .

Problem with Thematic Roles

Difficult to have a good set of roles that works all the time,
where each role can have a small, concrete definition

47 high-level classes, divided into 193 more specific classes
- Levin (1993), VerbNet

Fewer Roles

PropBank

“Proto”-arguments, shared across verbs
Exact definition depends on verb sense

More Roles

FrameNet

Each verb sense is part of a “frame”
Each frame has its own arguments

Prop Bank

- “Frames” are verb senses
- Arguments of each verb are mapped onto Arg0, Arg1, Arg2
- Arguments are always constituents (annotated over syntax)

fall.01 (move downward)

- ▶ ARG1: logical subject, patient, thing falling
- ▶ ARG2: extent, amount fallen
- ▶ ARG3: starting point
- ▶ ARG4: ending point
- ▶ ARG-M-LOC: medium

fall.08 (fall back on)

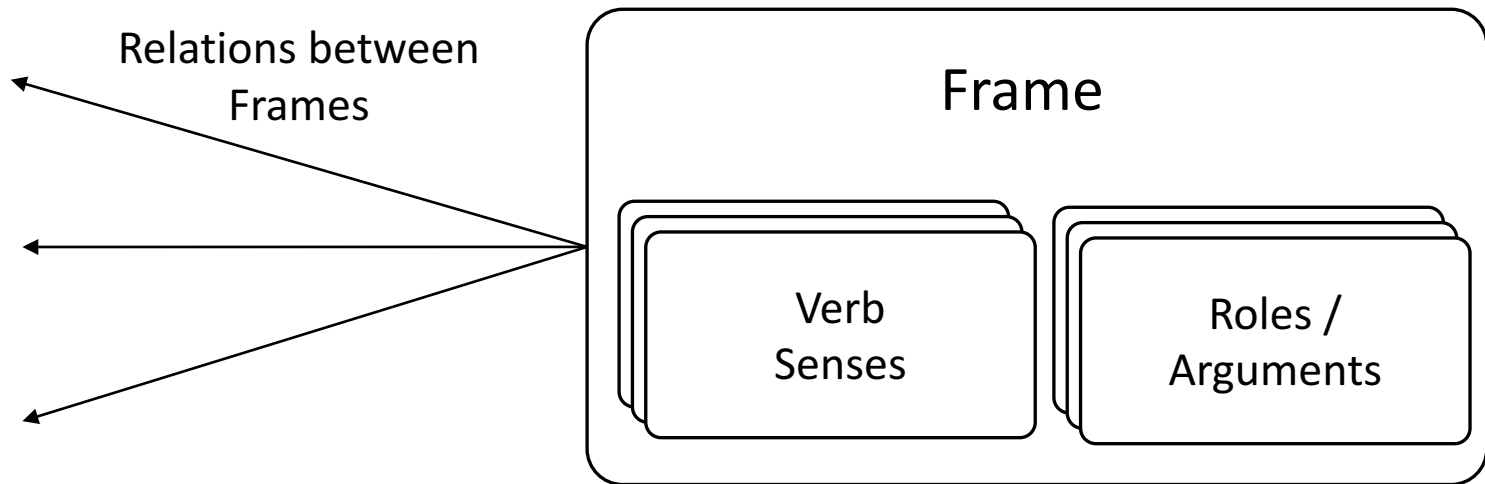
- ▶ ARG0: thing falling back
- ▶ ARG1: thing fallen back on

fall.10 (fall for a trick)

- ▶ ARG1: the fool
- ▶ ARG2: the trick

FrameNet

- “Frames” can be any content word (~1000 frames)
- Each frame has its own argument roles, everything is hierarchical
- Annotated without syntax, arguments can be anything



“Change position on a scale”

VERBS:	dwindle	move	soar	escalation	shift
advance	edge	mushroom	swell	explosion	tumble
climb	explode	plummet	swing	fall	
decline	fall	reach	triple	fluctuation	ADVERBS:
decrease	fluctuate	rise	tumble	gain	increasingly
diminish	gain	rocket		growth	
dip	grow	shift	NOUNS:	hike	
double	increase	skyrocket	decline	increase	
drop	jump	slide	decrease	rise	

“Change position on a scale”

Core Roles	
ATTRIBUTE	The ATTRIBUTE is a scalar property that the ITEM possesses.
DIFFERENCE	The distance by which an ITEM changes its position on the scale.
FINAL_STATE	A description that presents the ITEM’s state after the change in the ATTRIBUTE’s value as an independent predication.
FINAL_VALUE	The position on the scale where the ITEM ends up.
INITIAL_STATE	A description that presents the ITEM’s state before the change in the ATTRIBUTE’s value as an independent predication.
INITIAL_VALUE	The initial position on the scale from which the ITEM moves away.
ITEM	The entity that has a position on the scale.
VALUE_RANGE	A portion of the scale, typically identified by its end points, along which the values of the ATTRIBUTE fluctuate.
Some Non-Core Roles	
DURATION	The length of time over which the change takes place.
SPEED	The rate of change of the VALUE.
GROUP	The GROUP in which an ITEM changes the value of an ATTRIBUTE in a specified way.

“Change position on a scale”

[ITEM Oil] *rose* [ATTRIBUTE in price] [DIFFERENCE by 2%].

[ITEM It] has *increased* [FINAL_STATE to having them 1 day a month].

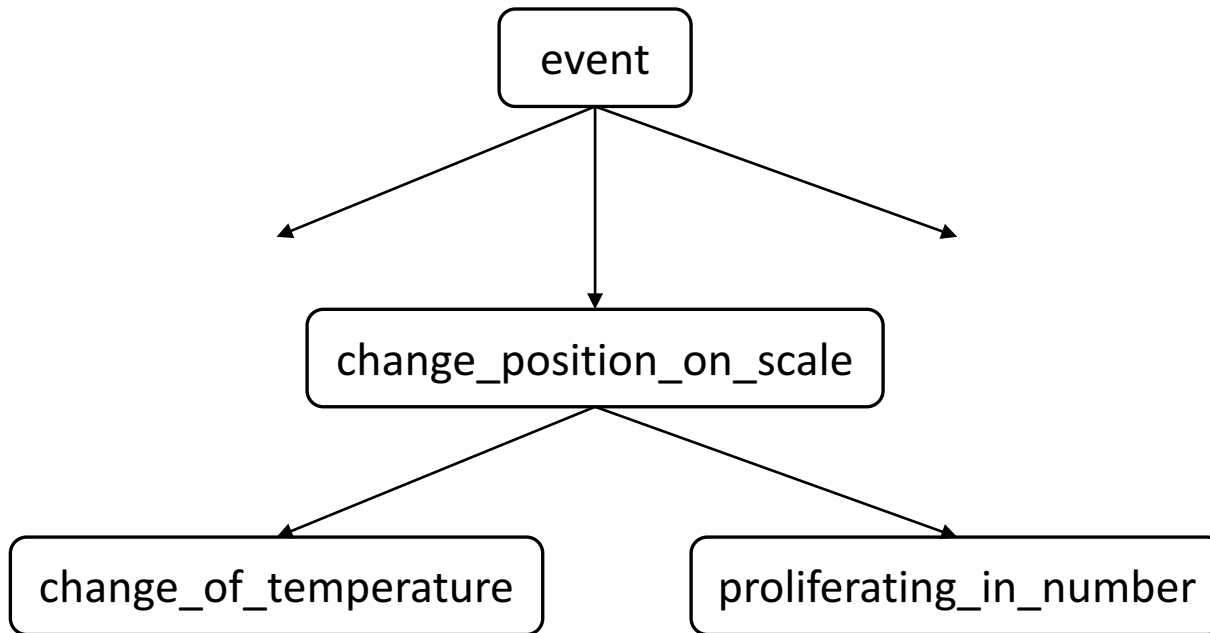
[ITEM Microsoft shares] *fell* [FINAL_VALUE to 7 5/8].

[ITEM Colon cancer incidence] *fell* [DIFFERENCE by 50%] [GROUP among men].

a steady *increase* [INITIAL_VALUE from 9.5] [FINAL_VALUE to 14.3] [ITEM in dividends]

a [DIFFERENCE 5%] [ITEM dividend] *increase...*

Relations between Frames



Inherits from:
Is Inherited by:
Perspective on:
Is Perspectivized in:
Uses:
Is Used by:
Subframe of:
Has Subframe(s):
Precedes:
Is Preceded by:
Is Inchoative of:
Is Causative of:

Semantic Role Labeling

You can't blame the program for being unable to identify it.

Cognizer

Evaluee

Reason

FrameNet

The San Francisco Examiner issued a special edition yesterday.

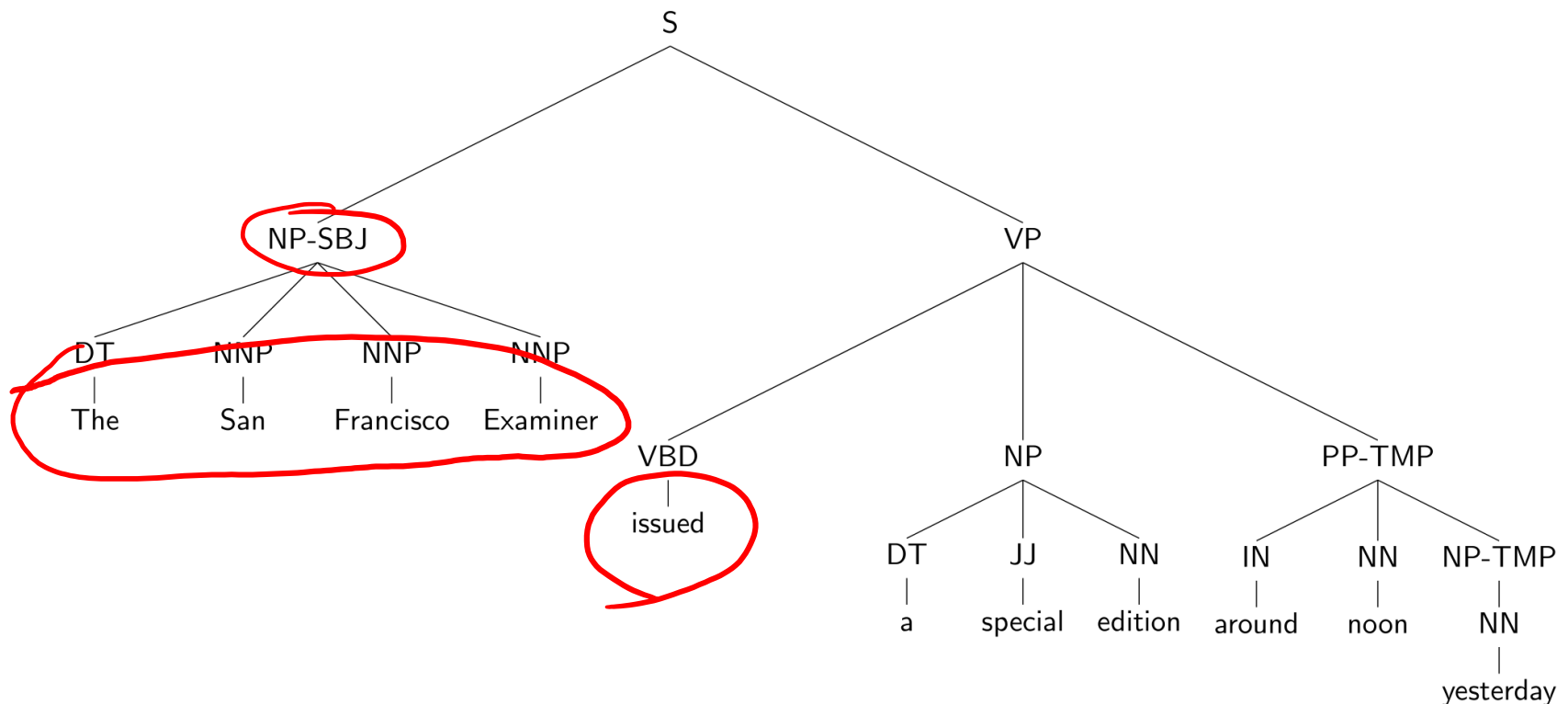
PropBank

Arg0

Arg1

ArgM-Tmp

Approach to SRL Predictions



Features for SRL

Headword of constituent: **Examiner**

Headword POS: **NNP**

Voice of the clause: **Active**

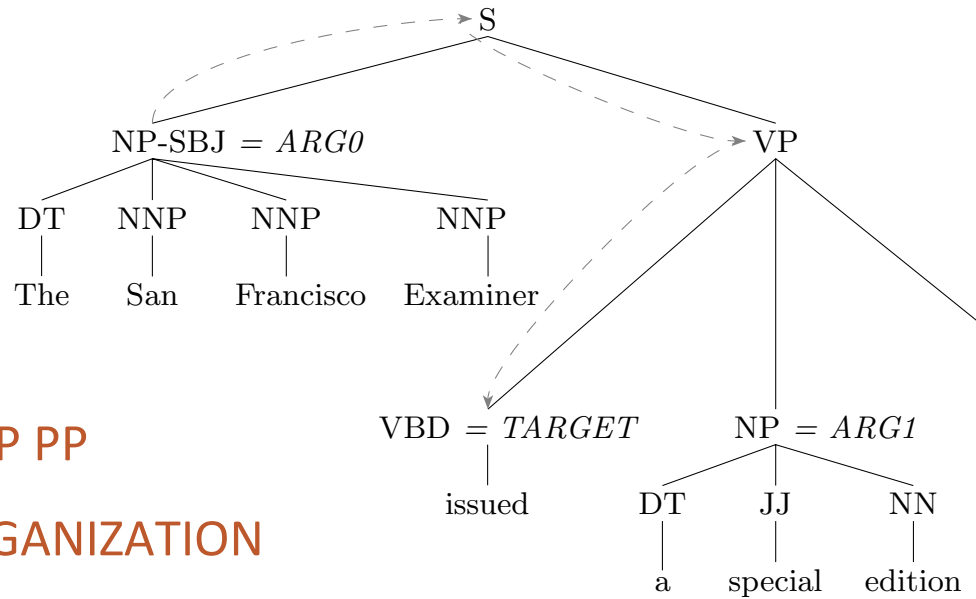
Subcategorization of pred: **VP -> VBD NP PP**

Named Entity type of constituent: **ORGANIZATION**

First and last words of constituent: **The, Examiner**

Linear position, clause re: predicate: **before**

Path features: **NP↑S↓VP↓VBD**



Typical SRL Pipeline

Pruning

Use rules to filter out unlikely constituents.

Identification

Use a classifier to further filter constituents.

Classification

Use a classifier predict multiple roles for each constituent.

Joint Inference

Jointly predict a consistent set of roles.

Selectional Restrictions

I want to eat **someplace nearby**.

Interpretation 1

someplace nearby is a location adjunct (intransitive)

Interpretation 2

someplace nearby is a direct object (transitive verb)



Why is Interpretation 2 unlikely?

Theme of “eat” is usually edible.

Introduce constraints based on WordNet
In this case, it should be “food, nutrient”

Selectional *Preferences!*

Instead of restrictions, measure **association scores** for each role.
how often a class/noun appears as an argument.

eat **food#n#1, aliment#n#1, entity#n#1, solid#n#1, food#n#2**
drink **fluid#n#1, liquid#n#1, entity#n#1, alcohol#n#1, beverage#n#1**
appoint **individual#n#1, entity#n#1, chief#n#1, being#n#2, expert#n#1**
publish **abstract_entity#n#1, piece_of_writing#n#1, communication#n#2, publication#n#1**

Classes

Nouns

Verb	Plaus./Implaus.
see	friend/method
read	article/fashion
find	label/fever
hear	story/issue
write	letter/market
urge	daughter/contrast
warn	driver/engine
judge	contest/climate

Upcoming...

Homework

- Homework 3 is due on **February 27**
- Write-up and data will be released very soon.

Project

- Status report due in ~2 weeks: **March 2, 2017**
- Instructions coming soon
- Only **5 pages**

Summaries

- Paper summaries: **February 17**, February 28, March 14
- Only **1 page** each