Semantics

Kevin Duh
Intro to NLP, Fall 2019

Outline

- Challenges
- Distributional Semantics
- Word Sense
- Semantic Role Labeling

The Challenge of Designing Semantic Representations

- Q: What is semantics?
- A: The study of meaning

- Q: What is meaning?
- A: …

We know it when we see it

- These sentences/phrases all have the same meaning:
  - XYZ corporation bought the stock.
  - The stock was bought by XYZ corporation.
  - The purchase of the stock by XYZ corporation...
  - The stock purchase by XYZ corporation...

But how to formally define it?

Sentence → **Meaning Representation**

Example Representations

Sentence: **“I have a car”**

$\exists e,y\ Having(e) \wedge Haver(e, Speaker) \wedge HadThing(e,y) \wedge Car(y)$

Logic Formula

$$
\begin{tikzcd}
 & \text{Having} \arrow[dl, bend right] \arrow[dr, bend left] & \\
\text{Haver} \arrow[d] & & \text{Had-Thing} \arrow[d] \\
\text{Speaker} & & \text{Car}
\end{tikzcd}
$$

Graph Representation

Car
$\Uparrow$ POSS-BY
Speaker

```
Having
 Haver:    Speaker
 HadThing:    Car
```

Key-Value Records

PEARSON
Speech and Language Processing, Second Edition
Daniel Jurafsky and James H. Martin

Example Representations

Sentence: "I have a car"

"Ich habe ein Auto"

As translation in another language

There's no single agreed-upon representation that works in all cases

- Different emphases:
  - Words or Sentences
  - Syntax-Semantics interface, Logical Inference, etc.
- Different aims:
  - "Deep (and narrow)" vs "Shallow (and broad)"
  - e.g. Show me all flights from BWI to NRT.
    - Do we link to actual flight records?
    - Or general concept of flying machines?

Outline

- Challenges
- Distributional Semantics
- Word Sense
- Semantic Role Labeling

Distributional Semantics

What information is needed for a good representation?

You shall know a word by the company it keeps. – J. R. Firth (linguist)

- Distributional Semantics: a word's meaning is based on its positional distribution in text

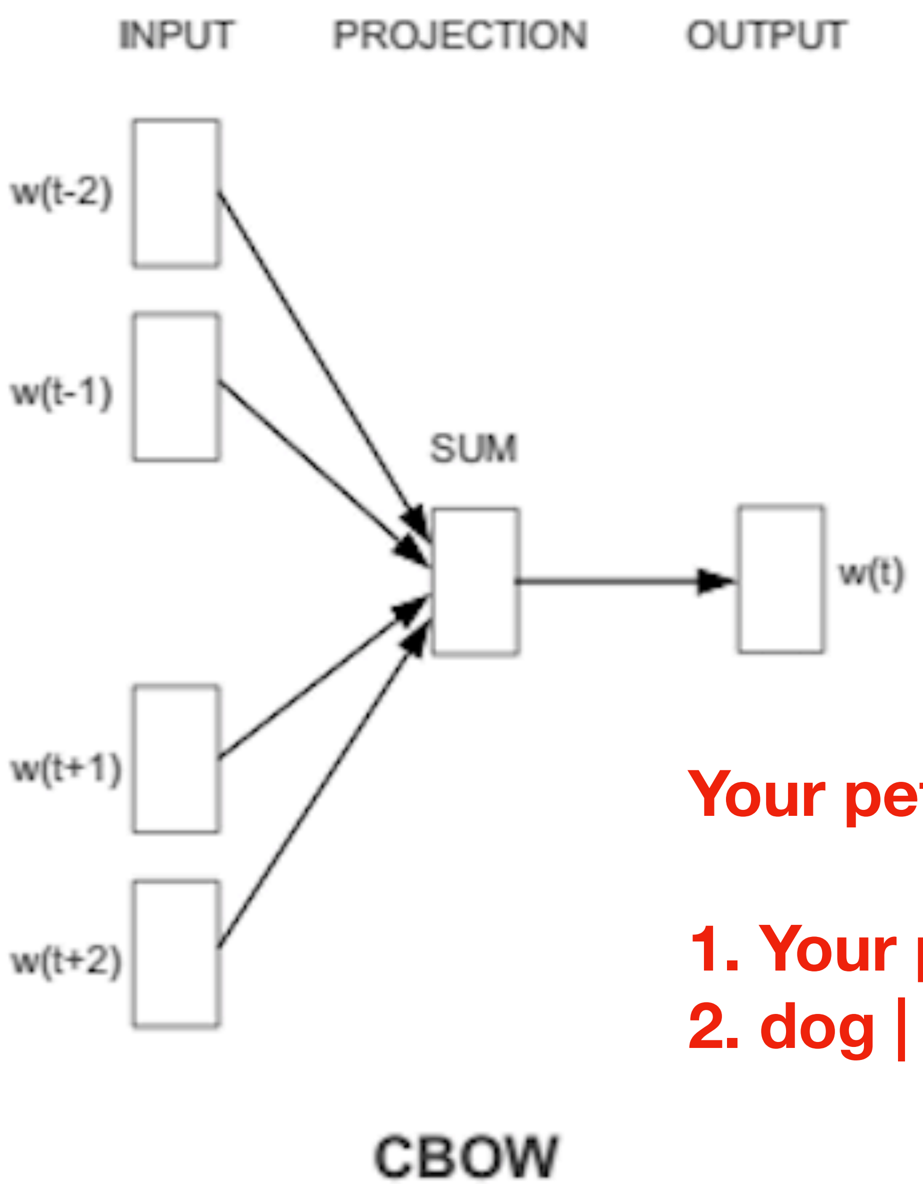
Learning Distributional Semantics from large text dataset

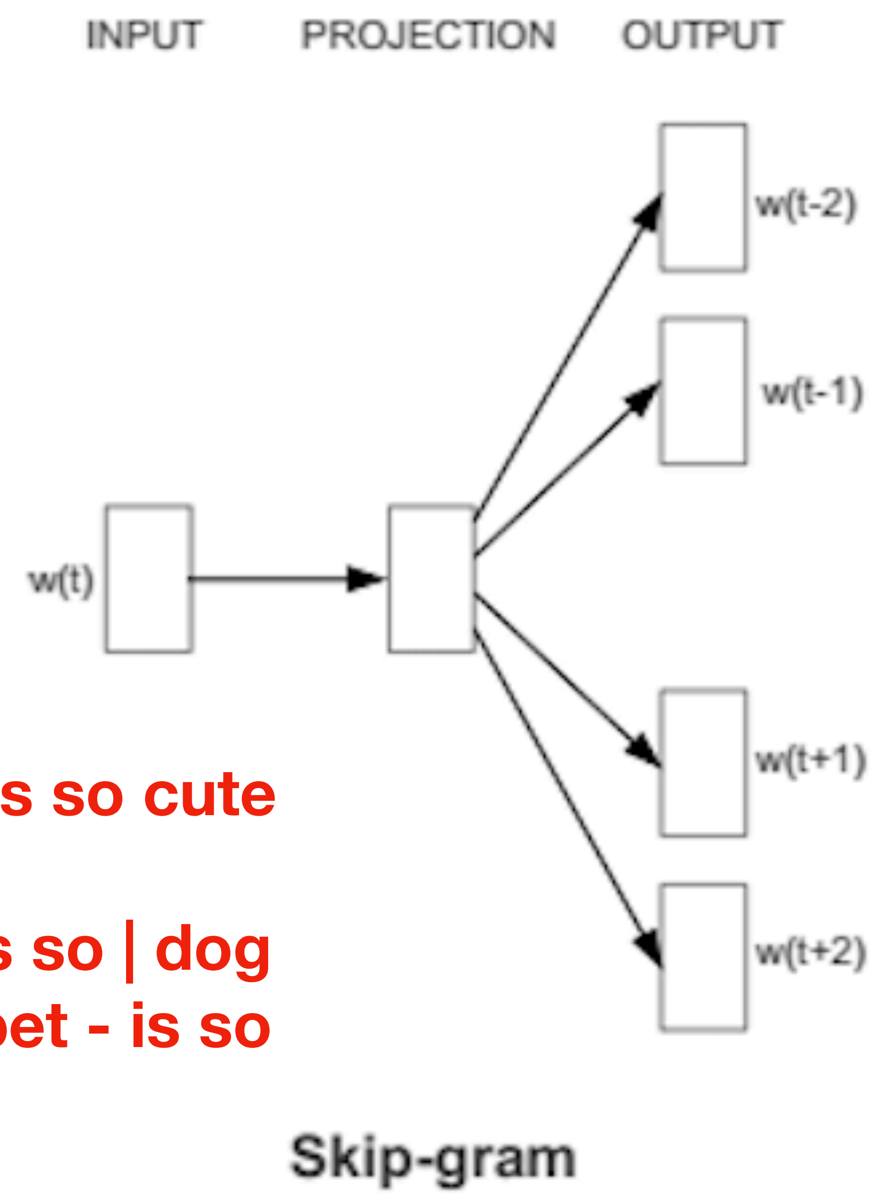
- Your pet dog is so cute
- Your pet cat is so cute
- The dog ate my homework
- The cat ate my homework

neighbor(dog) overlaps-with neighbor(cats)

so meaning(dog) is-similar-to meaning(cats)

Word2Vec implements Distribution Semantics





Your pet dog is so cute

1. **Your pet - is so | dog**
2. **dog | Your pet - is so**

From: Mikolov, Tomas; et al. (2013). "Efficient Estimation of Word Representations in Vector Space"

Latent Semantic Analysis (LSA) also implements Distributional Semantics

Document-Term Matrix

	pet	dog	is	cat	the	ate
S1	1	1	1	0	0	0
S2	1	0	1	1	0	0
S3	0	1	0	0	1	1
S4	0	0	0	1	1	1

S1: ... *pet dog is* ...
S2: ... *pet cat is* ...
S3: *The dog ate* ...
S4: *The cat ate* ...

= Document - Latent Topic Matrix *x* Singular Values *x* Latent Topic - Word Matrix

Word Embeddings

Pet-peeve: fundamentally, neural approaches aren't so different from classical LSA. They just use more GPUs!

Advantages of Distributional Semantics

- Do you know what's a **bar-ba-loot**?
- What is a more likely sentence?
    1. **Bar-ba-loots like to eat fruits**
    2. **The pirate ship Bar-ba-loots looted Barbados**
- What if I tell you: **vector**(Bar-ba-loots) **~ vector**(bear)

Advantages of Distributional Semantics

- Similarity metric between vectors allow processing of related words

Bar-ba-loots from Dr. Seuss' children books

Outline

- Challenges
- Distributional Semantics
- $\boxed{\text{Word Sense}}$
- Semantic Role Labeling

Word Sense

- Senses of the word **bank**:
  - The bank[1] is investing in CDO's.
  - The river bank[2] is flooding.
  - The food bank[3] is providing free meals.
  - The bank[4] is at the corner of 1st and Main St.
- bank[1] & bank[2] are **homonyms** (coincidentally same sound/orthography, otherwise unrelated in meaning)
- bank[1] & bank[3] exhibit **polysemy** (related meaning: "a repository for stuff")
- bank[4] shows there's a relationship between BUILDING and INSTITUTION

WordNet

<u>Hypernym</u>:

dog is-a-kind-of canine

to butt is-a-kind-of to hit

<u>Meronym</u>:

window is-part-of building

<u>Entailment</u>:

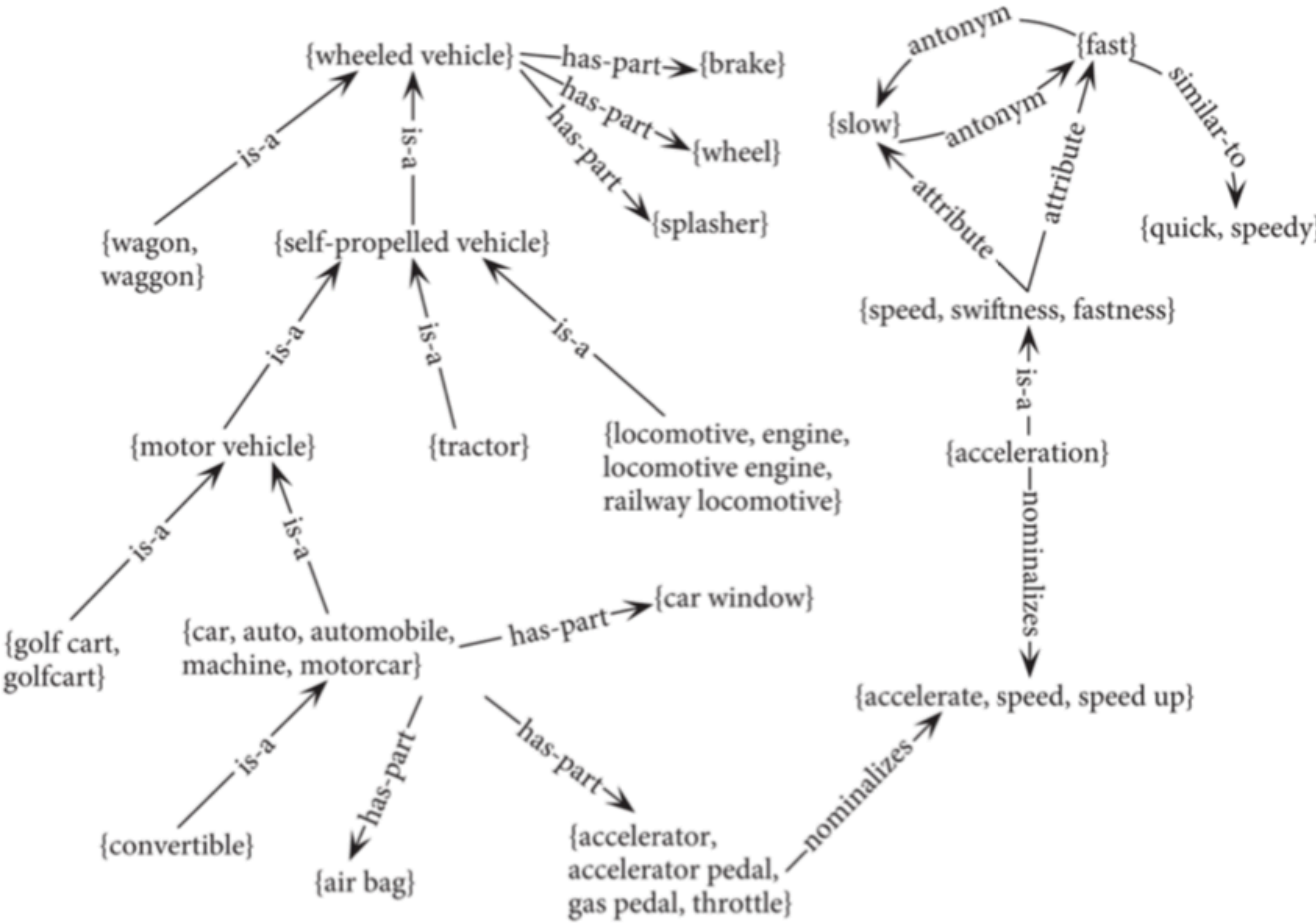
to sleep is entailed by to snore

George Miller,
WordNet founder

Note: Relation is defined in terms of synsets, not words (as this simplified slide might suggest)

Synset

- When senses of two different words are similar, we say they're synonyms
  - e.g. couch & sofa; bank & repository
- Instead of talking about two words being synonyms, we talk of synset as set of senses that are similar
  - e.g. couch^1 & sofa^1; bank^1 & repository^2



From Jurafsky & Martin, Speech & Language Processing, 3rd ed. https://web.stanford.edu/~jurafsky/slp3/19.pdf; Derived from: Navigli (2016). Chapter 20. Ontologies. In Mitkov, R. (Ed.), The Oxford handbook of computational linguistics. Oxford University Press.

WordNet Search - 3.1

- WordNet home page - Glossary - Help

https://wordnet.princeton.edu

Word to search for: serve [Search WordNet]

Noun

- S: (n) **serve#1**, service#12 ((sports) a stroke that puts the ball in play) *"his powerful serves won the game"*

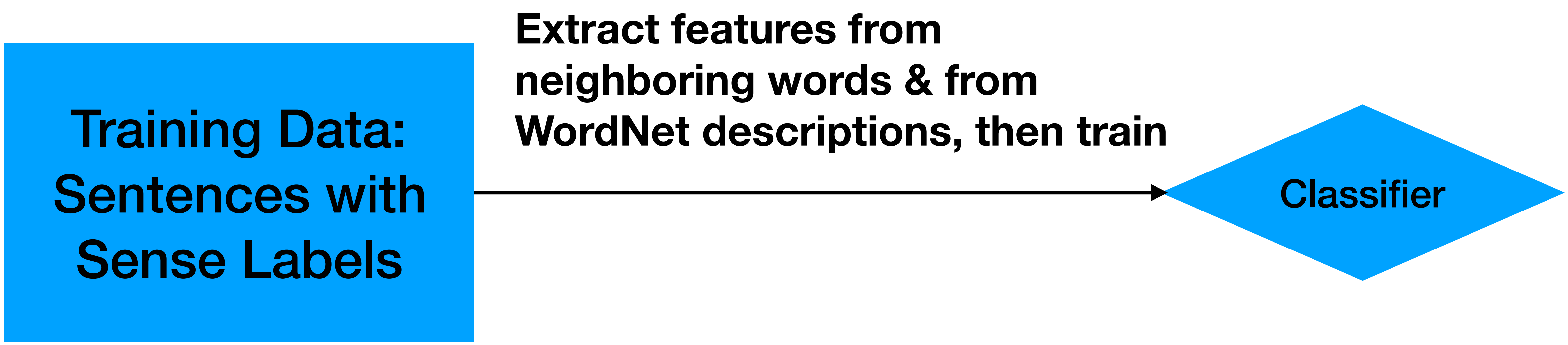
Verb

- (55)S: (v) **serve#1**, function#2 (serve a purpose, role, or function) *"The tree stump serves as a table"; "The female students served as a control group"; "This table would serve very well"; "His freedom served him well"; "The table functions as a desk"*
- (36)S: (v) **serve#2** (do duty or hold offices; serve in a specific function) *"He served as head of the department for three years"; "She served in Congress for two terms"*
- (24)S: (v) **serve#3** (contribute or conduce to) *"The scandal served to increase his popularity"*
- (23)S: (v) service#1, **serve#4** (be used by; as of a utility) *"The sewage plant served the neighboring communities"; "The garage served to shelter his horses"*
- (21)S: (v) **serve#5**, help#5 (help to some food; help with food or drink) *"I*

Word Sense Disambiguation (WSD)

- Input Sentence: He served as Secretary of State
- Task: What sense is served?
  - $serve^1$, $serve^2$, $serve^3$, $serve^4$?

Supervised methods for WSD



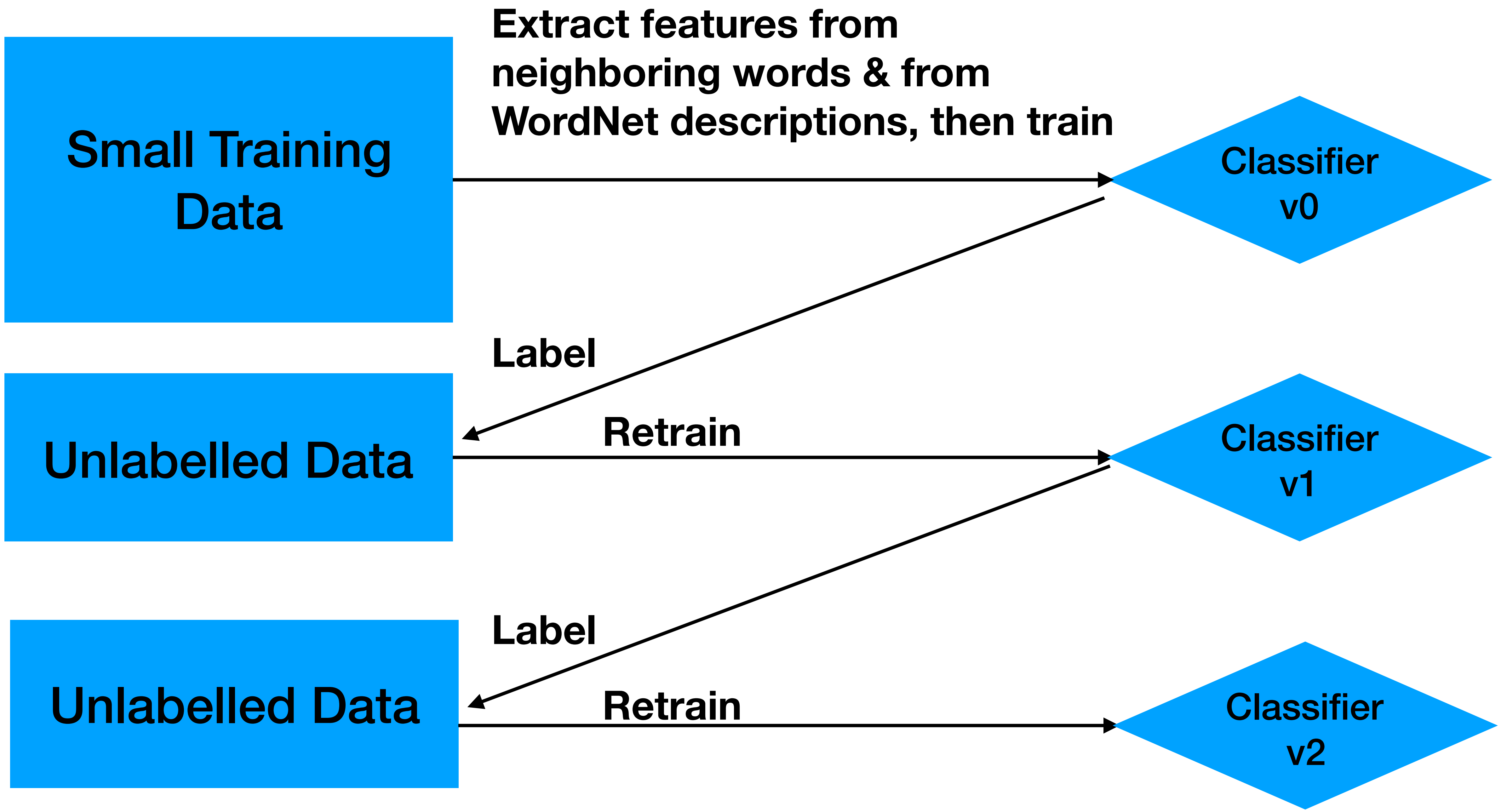
Try to capture selectional preferences:

Example:

1. **I hate washing dishes**
2. **I can stir-fry some simple dishes**

There is little ambiguity in dishes^1 (a physical plate) vs dishes^2 (a particular food item, like Chicken Fried Rice) for us because:
- washing and stir-fry "select" for different kinds of objects

Semi-Supervised methods for WSD: Yarowsky Algorithm



Outline

- Challenges
- Distributional Semantics
- Word Sense
- Semantic Role Labeling

Who did what to whom

- Jerry hit Tom with a hammer today
- Today, Tom was hit by Jerry with a hammer
- With a hammer, Tom hit Jerry today

Instrument of hitting

Agent of hitting

Patient of hitting

Temporal Adjunct

Thematic Roles

- Agent: volitional causer for an event. “The waiter spilled the soup”
- Experiencer: the experiencer of an event. “John has a headache”
- Theme: the participant most directly effected by the event. “Fred threw the rock”
- Result: the end product of an event. “The government has built a stadium.”
- Force: the non-volitioner cause of an event. “The wind blew things away”
- Instrument: an instrument used in an event

Alternatives to thematic roles

- It's difficult to create a standard set of roles
- Solutions:
  - Fewer roles: each role is more general —> PropBank
  - More roles: define roles specific to each group of predicate —> FrameNet

PropBank roles

- Each verb sense has numbered argument:
  - Arg0: Proto-Agent
  - Arg1: Proto-Patient
  - Arg2-Arg5: depends on the verb sense, includes benefactive, instrument, attribute, end state, ..
  - ArgM-: modifiers or adjuncts
- These are annotated on top of a syntactic parse

PropBank Example

- increase.01 “go up incrementally”
  - Arg0: Proto-Agent - causer of increase
  - Arg1: Proto-Patient - thing increased
  - Arg2: Amount increased
  - Arg3: Start point; Arg4: End point
- Now we can see these sentences have similar meanings
  - [Arg0 The shop] increased [Arg1 the price] [Arg3 today]
  - [Arg1 The price] increased [Arg2 10%] [Arg0 by the shop]

FrameNet

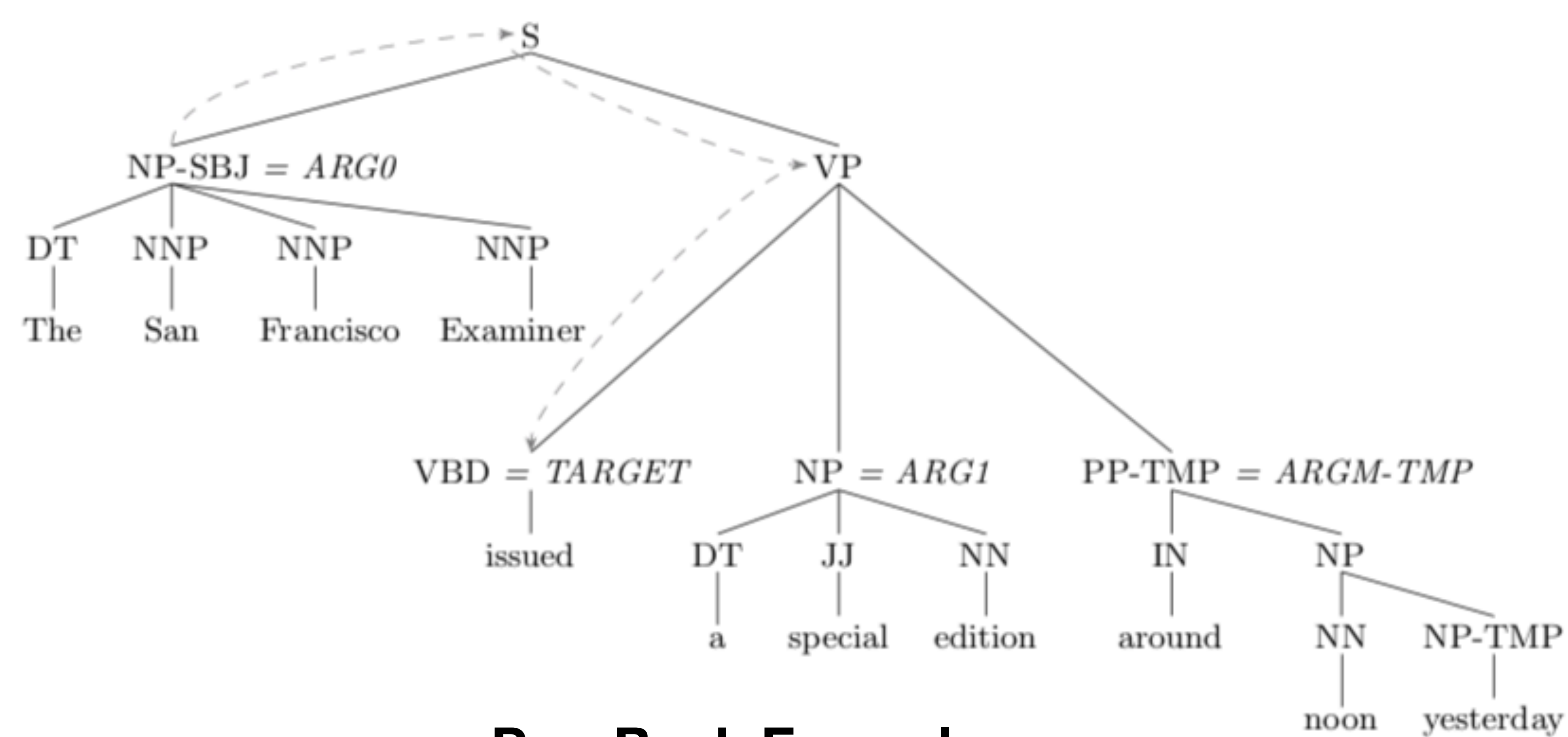
- These different forms of “increase” are related:
  - [Arg1 The price] <u>increased</u> [Arg2 10%]
  - [Arg1 The price] <u>rose</u>
  - There has been a [Arg2 10%] <u>rise</u> [Arg1 in the price]
- Let’s define a frame: **change_position_on_a_scale**, with elements like item’s attribue, initial/final value, difference
  - Verbs evoking this frame: rise, increase, jump, grow,…
  - Nouns evoking this frame: rise, increase, growth, escalation,…
  - [Item The price] <u>increased</u> [Difference 10%]
  - There has been a [Difference 10%] <u>rise</u> [Item in the price]

Semantic Role Labeling Task Formulation (there are variants)

- Determine the semantic role of constituents of a sentence, given the predicate

Task 1: Identification

Task 2: Classification



PropBank Example

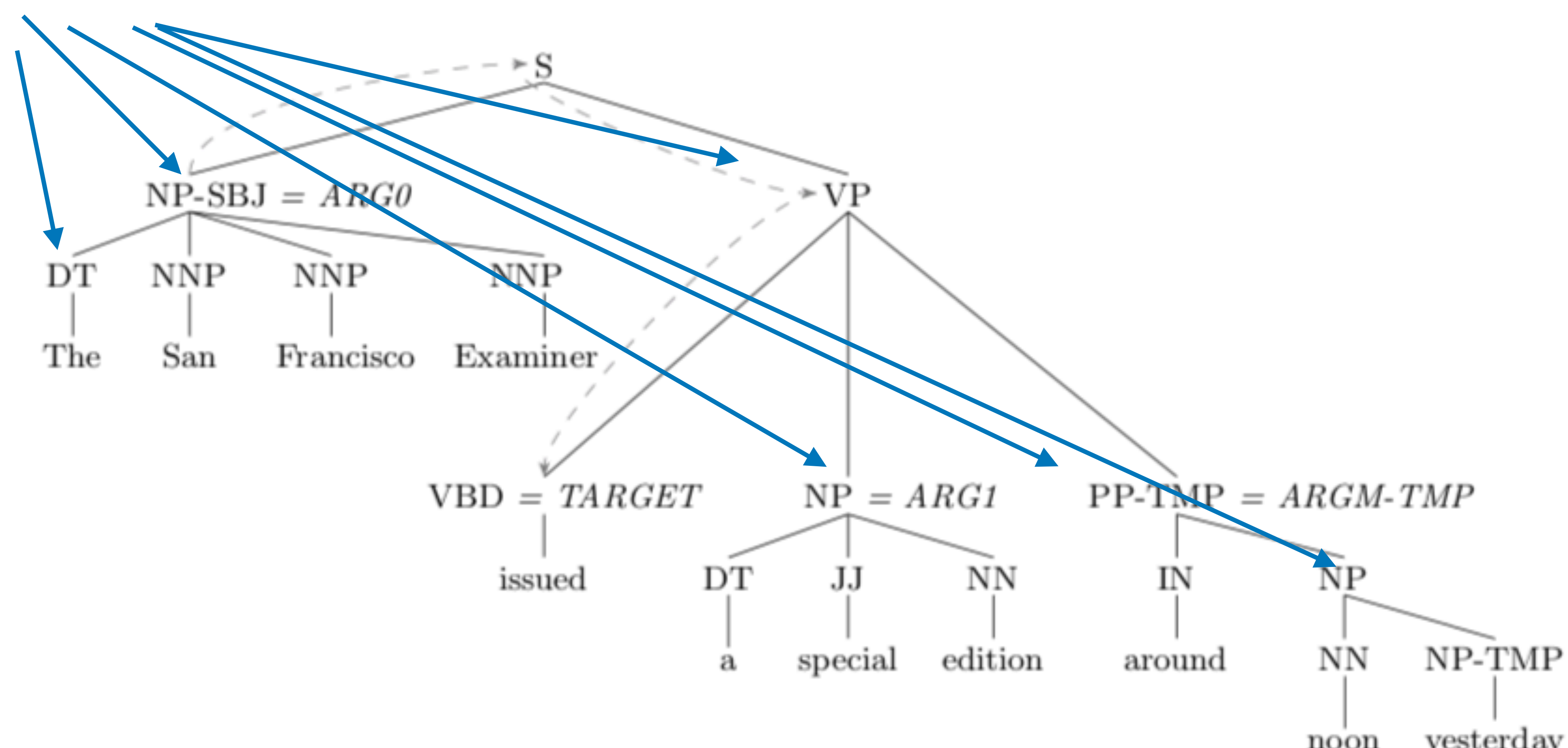
Semantic Role Labeling Task Formulation (there are variants)

- Determine the semantic role of constituents of a sentence, given the predicate

Task 1: Identification

Task 2: Classification

Are these spans possible arguments for the predicate “issued”? Yes/No



PropBank Example

Semantic Role Labeling Task Formulation (there are variants)

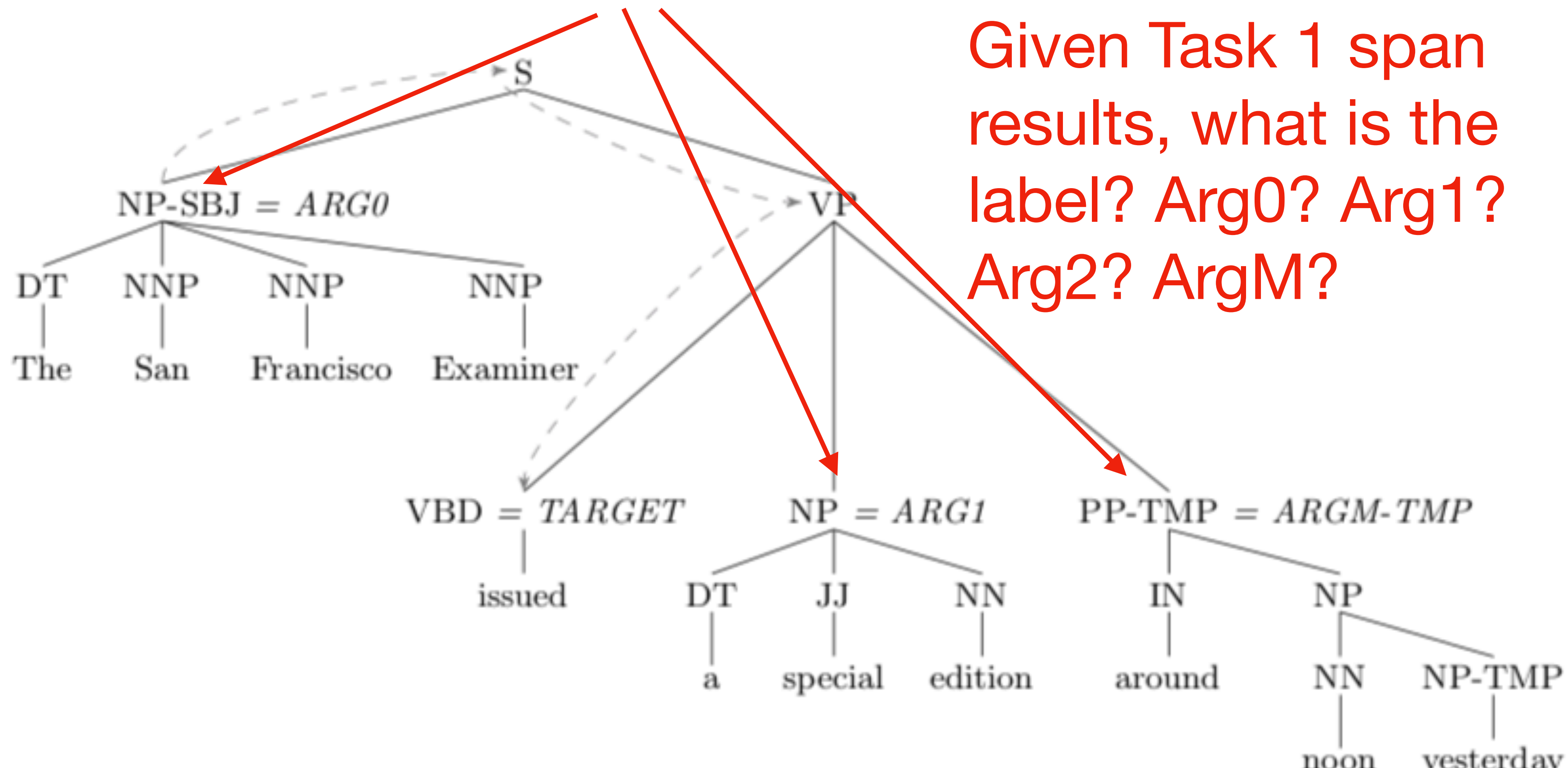
- Determine the semantic role of constituents of a sentence, given the predicate

Task 1: Identification

Are these spans possible arguments for the predicate "issued"? Yes/No

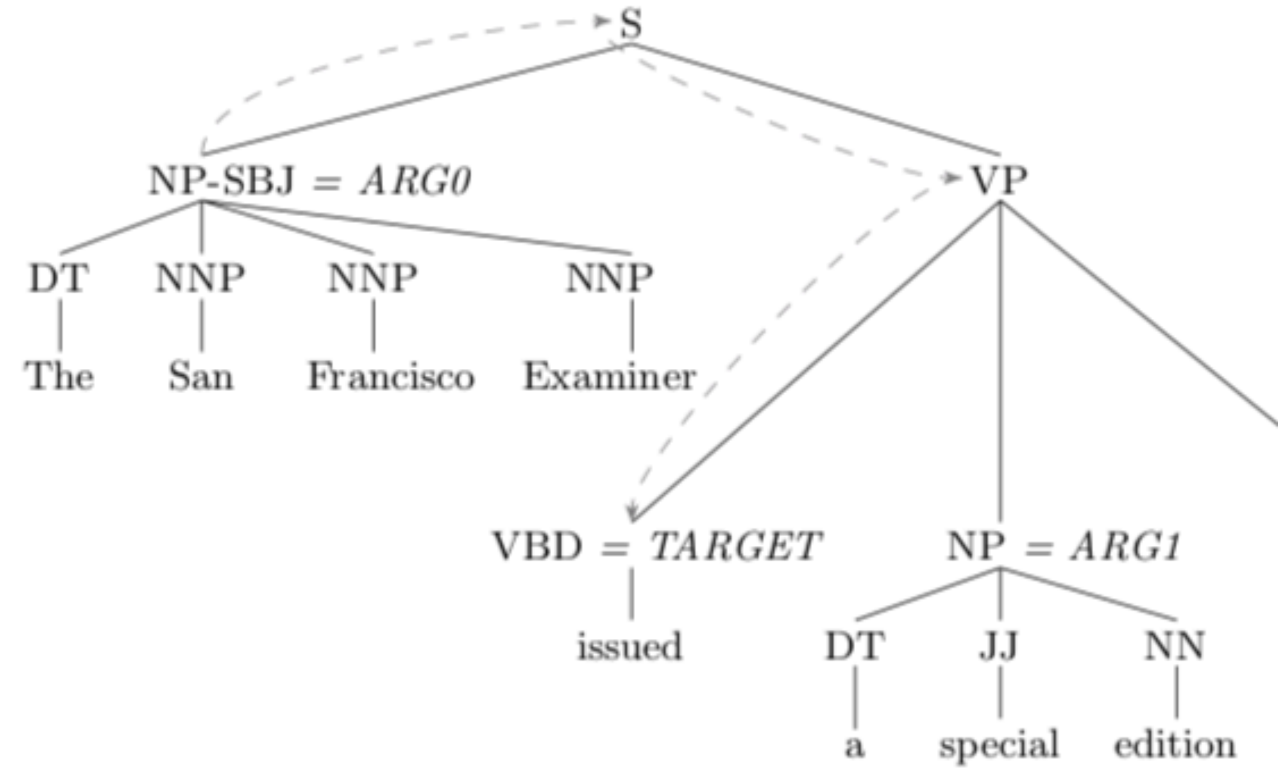
Task 2: Classification

Given Task 1 span results, what is the label? Arg0? Arg1? Arg2? ArgM?



PropBank Example

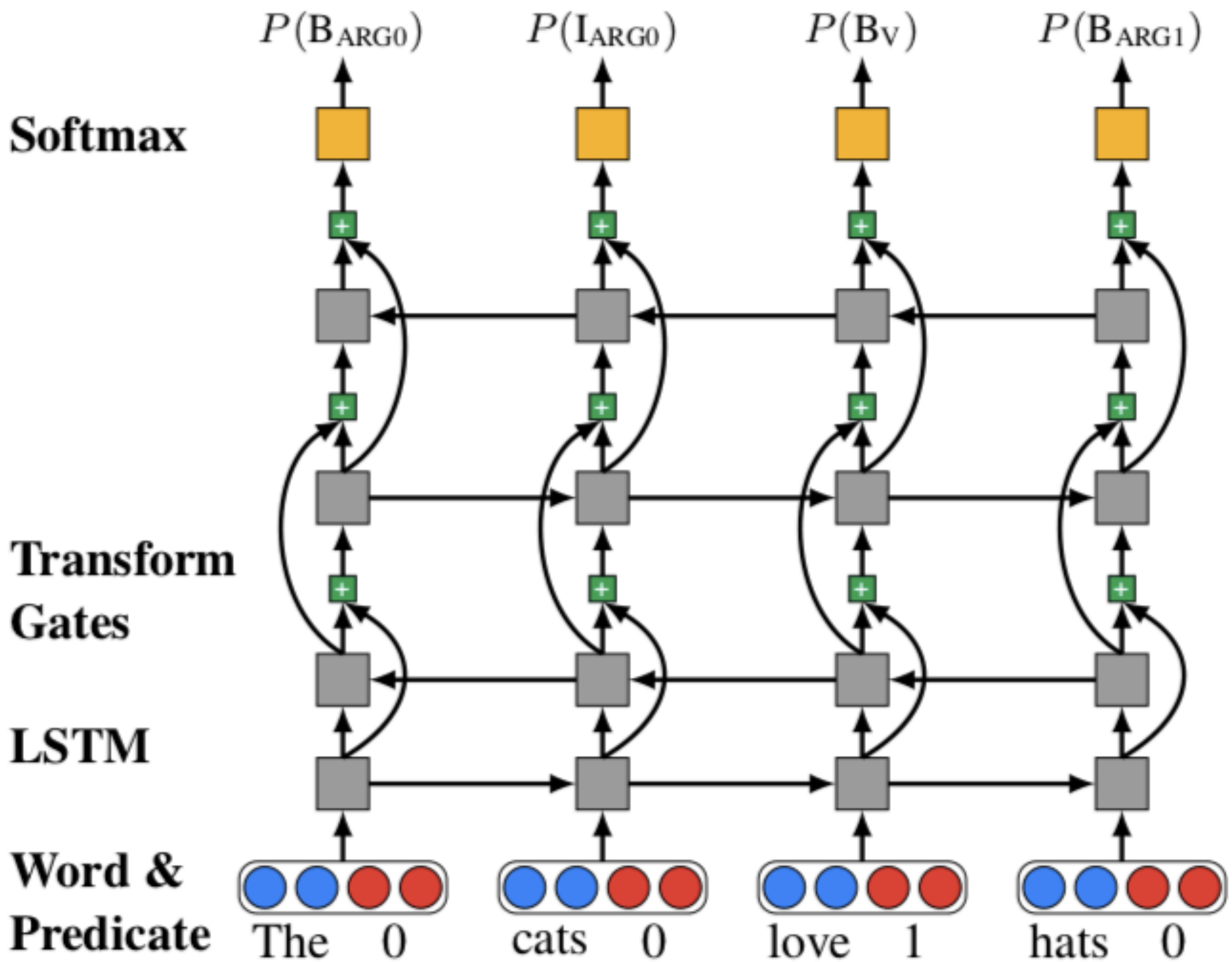
Models for SRL (1)



- Log-linear classifier for each task
- Features include:
    - headword/POS of constituent
    - voice (active or passive)
    - grammar rule (subcategorization) for predicate VP->VBD NP PP
    - named entity type (The San Fransisco Examiner = ORGANIZATION)
    - path in tree from constituent to predicate: NP↑S↓VP↓VBD
- Apply classifier to each node on tree

Models for SRL (2)

- Formulate as sequence labeling (BIO encoding)



He et. al. (2017) Deep SRL. What works and what's next
https://kentonl.com/pub/hllz-acl.2017.pdf

Summary

- Challenges: Many ways to define "semantics"
- Distributional Semantics: "You shall know a word by the company it keeps." e.g. Word2Vec
- Word Sense: Synsets & WordNet relations
- Semantic Role Labeling:
  - Who did what to whom.
  - Thematic roles, PropBank, FrameNet