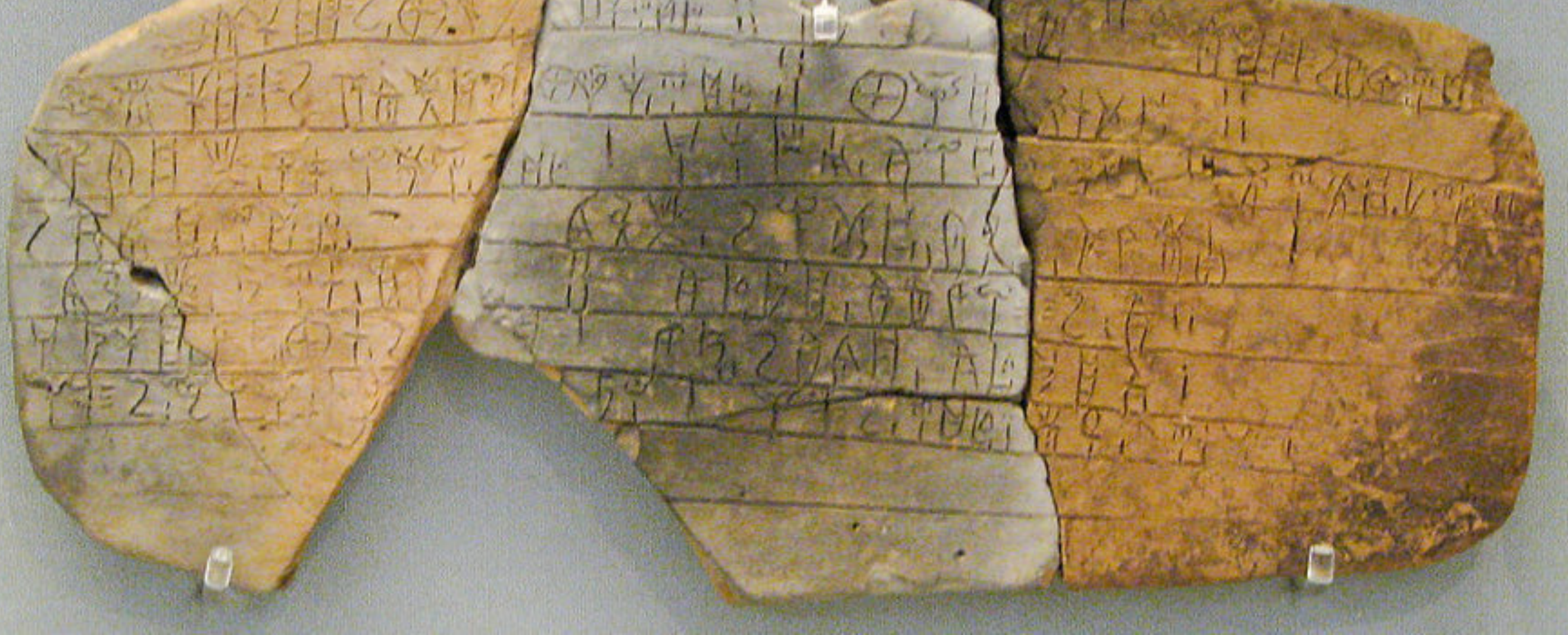




Natural Language Processing

Info 159/259

Lecture 20: Semantic roles (Nov.1, 2018)

David Bamman, UC Berkeley

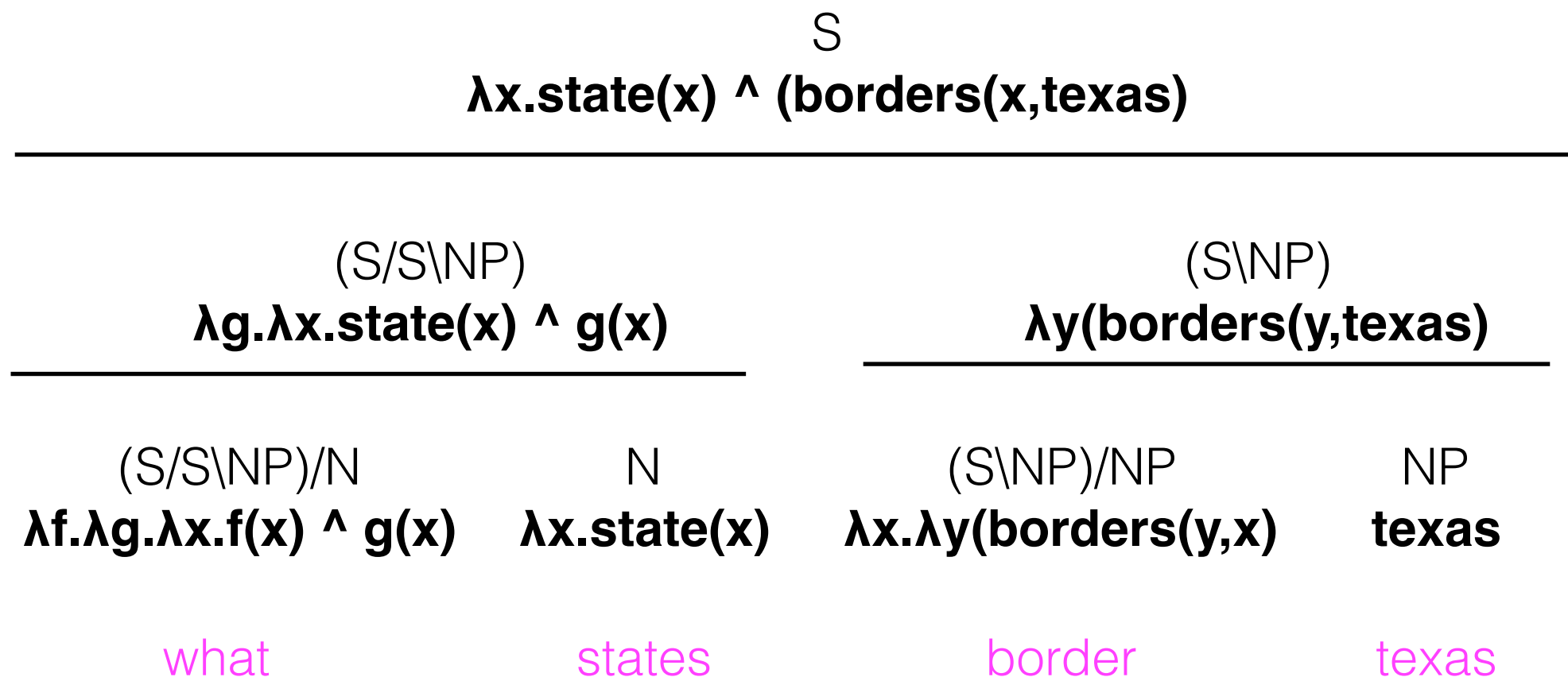
Semantic parsing

- Semantic parsing with CCG is simply syntactic parsing, assuming mapping from syntactic primitives to logical forms.
- But this encounters two problems:
 - We don't have those manual mappings (task-specific).
 - We can't parse anything not in our lexicon.

Learning from logical forms

- We can train a semantic parser in a number of ways:
 - Full derivational trees (CCGBank)
 - Logical forms (Zettlemoyer and Collins 2005)
 - Denotations (Berant et al. 2013)

Learning from trees



Learning from logical forms

sentence	what states border texas
logical form	$\lambda x.\text{state}(x) \wedge \text{borders}(x, \text{texas})$

Two core ideas:

- We'll learn the lexicon (including the lambda expressions)
- We'll learn CCG parser from that lexicon, and treat the true tree as a **latent variable**

Learning from logical forms

- For all <sentence, logical form> pairs in training data, maximize the probability of the logical form by marginalizing over the joint probability:

$$P(L \mid S; \theta) = \sum_T P(L, T \mid S; \theta)$$

Start with random values for θ ;
update with SGD

- Where

$$P(L, T \mid S; \theta) = \frac{\exp(f(L, T, S)^\top \theta)}{\sum_{L, T} \exp(f(L, T, S)^\top \theta)}$$

Learning from logical forms

- Learning from logical forms is means we don't need training data in the form of **full CCG derivations** + semantically enriched **lexicon**.
- But we do still need training data in the form of logical forms.

Utah borders Idaho	borders(utah,idaho)
number of dramas starring tom cruise	???

Learning from denotations

sentence	what states border texas
logical form	$\lambda x.\text{state}(x) \wedge \text{borders}(x, \text{texas})$
denotation	new_mexico, oklahoma, arkansas, louisiana

sentence	number of dramas starring tom cruise
logical form	$\text{count}(\lambda x.\text{genre}(x, \text{drama}) \wedge \exists y.\text{performance}(x, y) \wedge \text{actor}(y, \text{tom\_cruise}))$
denotation	28

Learning from denotations

sentence	what states border texas
logical form	$\lambda x.\text{state}(x) \wedge \text{borders}(x, \text{texas})$
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denotation	28

Learning from denotations

- How could we use the principles of **learning from logical forms** to learn from denotations?
- The meaning of a sentence is the set of possible worlds consistent with that statement.

Utah borders Idaho	TRUE
number of dramas starring tom cruise	28

Learning from denotations

- Basic idea: maximize the probability of the tree T / logical form z that, when executed against a knowledge base $\mathcal{K}$, yield the correct denotation y

$$\sum_{i=1}^N \log \sum_{T: \llbracket T.z \rrbracket_{\mathcal{K}} = y_i} P(T \mid S_i, \theta)$$

objective function

Why do we need CCG (or a syntactic representation) at all?

- It provides the scaffolding for learning by encoding our assumptions about the problem (compositionality)
- Meaning is built from parts, so let's learn to decompose our answers (denotations, logical forms) into those parts.

Event semantics

Pat gives Sal a book

$\exists x. \text{book}(x) \wedge \text{GIVE}(\text{Pat}, \text{Sal}, x)$

Event semantics

Yesterday, Pat gave Sal a book reluctantly

$\exists x.\text{book}(x) \wedge \text{GIVE}(\text{Pat}, \text{Sal}, x, \text{yesterday}, \text{reluctantly})$

- One option: extend the arity of the relation (require more arguments)
- But that's not great because we need a separate predicate for every possible combination of arguments (even those that aren't required).

Event semantics

We can reify the event to an existentially quantified variable of its own, and then use it as an argument in other relations.

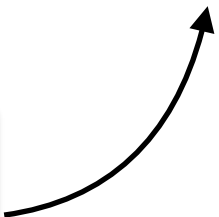
$$\begin{aligned} &\exists e, x. \text{GIVE-EVENT}(e) \\ &\wedge \text{GIVER}(e, \text{Pat}) \\ &\wedge \text{GIFT}(e, x) \\ &\wedge \text{BOOK}(x) \\ &\wedge \text{RECIPIENT}(e, \text{Sal}) \\ &\wedge \text{TIME}(e, \text{yesterday}) \\ &\wedge \text{MANNER}(e, \text{reluctantly}) \end{aligned}$$

Event semantics

Neo-Davidson event semantics: the event is central, and relations are predicated of the event. Each argument of an event holds its own relation.

$$\begin{aligned} &\exists e, x. \text{GIVE-EVENT}(e) \\ &\wedge \text{GIVER}(e, \text{Pat}) \\ &\wedge \text{GIFT}(e, x) \\ &\wedge \text{BOOK}(x) \\ &\wedge \text{RECIPIENT}(e, \text{Sal}) \\ &\wedge \text{TIME}(e, \text{yesterday}) \\ &\wedge \text{MANNER}(e, \text{reluctantly}) \end{aligned}$$

In model-theoretic semantics, each of these has a denotation in a world model



Event semantics

Sasha broke the window

$$\begin{aligned} &\exists e, y. \text{BREAKING-EVENT}(e) \\ &\wedge \text{BREAKER}(e, \text{Sasha}) \\ &\wedge \text{BROKEN-THING}(e, y) \\ &\wedge \text{WINDOW}(y) \end{aligned}$$

Pat opened the door

$$\begin{aligned} &\exists e, y. \text{OPENING-EVENT}(e) \\ &\wedge \text{OPENER}(e, \text{Pat}) \\ &\wedge \text{OPENED-THING}(e, y) \\ &\wedge \text{DOOR}(y) \end{aligned}$$

Event semantics

In model-theoretic semantics, each of these has some denotation in the world model.

Example: **WINDOW** has a identifier in some knowledge base (e.g., Freebase) uniquely identifying its properties.

$$\begin{aligned} &\exists e, y. \text{BREAKING-EVENT}(e) \\ &\wedge \text{BREAKER}(e, \text{Sasha}) \\ &\wedge \text{BROKEN-THING}(e, y) \\ &\wedge \text{WINDOW}(y) \end{aligned}$$
$$\begin{aligned} &\exists e, y. \text{OPENING-EVENT}(e) \\ &\wedge \text{OPENER}(e, \text{Pat}) \\ &\wedge \text{OPENED-THING}(e, y) \\ &\wedge \text{DOOR}(y) \end{aligned}$$

Event semantics

This requires a
comprehensive
representation of the
world

$$\begin{aligned} &\exists e, y. \text{BREAKING-EVENT}(e) \\ &\wedge \text{BREAKER}(e, \text{Sasha}) \\ &\wedge \text{BROKEN-THING}(e, y) \\ &\wedge \text{WINDOW}(y) \end{aligned}$$
$$\begin{aligned} &\exists e, y. \text{OPENING-EVENT}(e) \\ &\wedge \text{OPENER}(e, \text{Pat}) \\ &\wedge \text{OPENED-THING}(e, y) \\ &\wedge \text{DOOR}(y) \end{aligned}$$

Shallow semantics

$\exists e, y. \text{EVENT}(e)$
 $\wedge \text{CAUSER-OF-ACTION}(e, \text{Sasha})$
 $\wedge \text{RECIPIENT-OF-ACTION}(e, y)$
 $\wedge \text{"window"}(y)$

$\exists e, y. \text{BREAKING-EVENT}(e)$
 $\wedge \text{BREAKER}(e, \text{Sasha})$
 $\wedge \text{BROKEN-THING}(e, y)$
 $\wedge \text{WINDOW}(y)$

$\exists e, y. \text{EVENT}(e)$
 $\wedge \text{CAUSER-OF-ACTION}(e, \text{Pat})$
 $\wedge \text{RECIPIENT-OF-ACTION}(e, y)$
 $\wedge \text{"door"}(y)$

$\exists e, y. \text{OPENING-EVENT}(e)$
 $\wedge \text{OPENER}(e, \text{Pat})$
 $\wedge \text{OPENED-THING}(e, y)$
 $\wedge \text{DOOR}(y)$

These roles have a lot in common: direct causal responsibility for the events, have volition, often animate

Shallow semantics

$\exists e, y. \text{EVENT}(e)$
 $\wedge \text{AGENT}(e, \text{Sasha})$
 $\wedge \text{THEME}(e, y)$
 $\wedge \text{"window"}(y)$

$\exists e, y. \text{EVENT}(e)$
 $\wedge \text{AGENT}(e, \text{Pat})$
 $\wedge \text{THEME}(e, y)$
 $\wedge \text{"door"}(y)$

$\exists e, y. \text{BREAKING-EVENT}(e)$
 $\wedge \text{BREAKER}(e, \text{Sasha})$
 $\wedge \text{BROKEN-THING}(e, y)$
 $\wedge \text{WINDOW}(y)$

$\exists e, y. \text{OPENING-EVENT}(e)$
 $\wedge \text{OPENER}(e, \text{Pat})$
 $\wedge \text{OPENED-THING}(e, y)$
 $\wedge \text{DOOR}(y)$

Shallow semantics

Agent: Sasha
Theme: window

$$\begin{aligned} &\exists e, y. \text{BREAKING-EVENT}(e) \\ &\wedge \text{BREAKER}(e, \text{Sasha}) \\ &\wedge \text{BROKEN-THING}(e, y) \\ &\wedge \text{WINDOW}(y) \end{aligned}$$

Agent: Pat
Theme: door

$$\begin{aligned} &\exists e, y. \text{OPENING-EVENT}(e) \\ &\wedge \text{OPENER}(e, \text{Pat}) \\ &\wedge \text{OPENED-THING}(e, y) \\ &\wedge \text{DOOR}(y) \end{aligned}$$

Thematic roles

Thematic roles capture the semantic commonality among arguments for different relations (predicates)

- John broke the window
- The window was broken by John

Different syntactic roles, but the same thematic role.

Thematic roles

Agent	The volitional causer of an event
Experiencer	The experiencer of an event
Force	The non-volitional causer of the event
Theme	The participant most directly affected by an event
Result	The end product of an event
Content	The proposition or content of a propositional event
Instrument	An instrument used in an event
Beneficiary	The beneficiary of an event
Source	The origin of the object of a transfer event
Goal	The destination of an object of a transfer event

Thematic roles

Agent	<i>The waiter</i> spilled the soup.
Experiencer	John has <i>a headache</i> .
Force	<i>The wind</i> blows debris from the mall into our yards.
Theme	Only after Benjamin Franklin broke <i>the ice</i> ...
Result	The city built <i>a regulation-size baseball diamond</i> ...
Content	Mona asked “ <i>You met Mary Ann at a supermarket?</i> ”
Instrument	He poached catfish, stunning them with <i>a shocking device</i> ...
Beneficiary	Whenever Ann makes hotel reservations for <i>her boss</i> ...
Source	I flew in from <i>Boston</i> .
Goal	I drove to <i>Portland</i> .

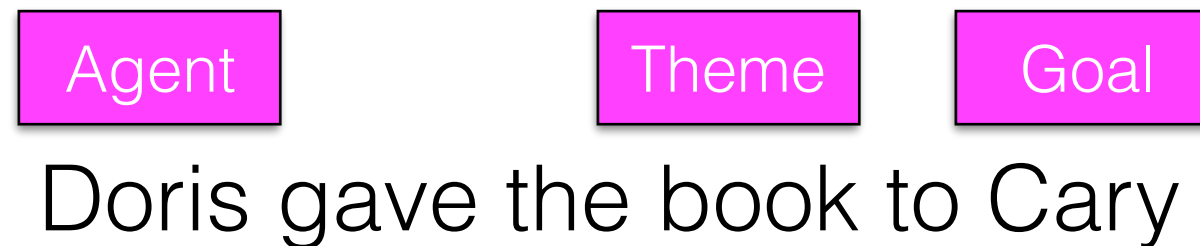
Thematic roles

Agent	The volitional causer of an event
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Source	The origin of the object of a transfer event
Goal	The destination of an object of a transfer event

- John broke the window
- The window was broken by John
- John broke the window with a rock
- The rock broke the window
- The window broke

Thematic roles

The thematic roles for verbs generally are predictable by the syntactic position of the argument (specific to each verb class). Some allow for consistent alternations:



Thematic roles

- Thematic roles are very useful but difficult to formally define AGENT, THEME, etc.
- At the same time, they may be too coarse for some applications.

Thematic roles

Intermediary instruments can be subjects

- The cook opened the jar with the new gadget
- The new gadget opened the jar
- Shelly ate the sliced banana with a fork
- *The fork ate the sliced banana

Enabling instruments cannot

Coarsening: Proto-roles

- Proto-roles = generalized thematic roles
- Proto-agent: causing an event, having volition wrt event, moving, acting with intention
- Proto-patient: change of state, causally affected by event)

Propbank

- Sentences from the [Penn Treebank](https://propbank.github.io) annotated with proto-roles, along with lexical entries for each sense of a verb identifying the specific meaning of each proto-role for that verb sense.

<https://propbank.github.io>

Propbank

(22.11) **agree.01**

Arg0: Agreer

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].

(22.12) **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%].

Propbank

- Verb-specific argument structures lets us map the commonalities among the different surface forms
 - [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%].

Propbank

- Verb-specific argument structures lets us map the commonalities among the different surface forms
 - [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%].

- [Arg1 The price of bananas] increased [Arg2 5%].
- [Arg1 The price of bananas] rose [Arg2 5%].
- There has been a [Arg2 5%] rise [Arg1 in the price of bananas].

FrameNet

- Propbank maps argument structure for individual verb senses
- FrameNet maps argument structure for frames, which are evoked by a lexical unit (typically a verb)

https://framenet.icsi.berkeley.edu/fndrupal/framenet_data

Frames

AI

- Schank and Abelson 1975, 1977
- Minsky 1974

Linguistics

- Fillmore 1975, 1982, Tannen 1979

Cognitive Psychology

- Rumelhart 1975, 1980

Sociology

- Goffman 1975

Media Studies

- Entman 1993

Frames

John went into a restaurant. He ordered a hamburger and coke. He asked the waitress for the check and left.

(Schank & Abelson 75)

Frames

- “A frame is a data-structure for representing a stereotyped situation” (Minsky 1975)
- By the term ‘frame’ I have in mind any system of concepts related in such a way that to understand any one of them you have to understand the whole structure in which it fits; when one of the things in such a structured is introduced ... all of the others are automatically made available.” (Fillmore 1982)

Who did what to whom?

commercial_transaction

- John **bought** the car at the dealership
- The car was **bought** by John
- John's **purchase** of the car
- The **sale** of the car cleared their inventory.

Who did what to whom?

Buyer

- John bought the car at the dealership
- The car was bought by John
- John's purchase of the car
- The sale of the car cleared their inventory.

Who did what to whom?

Thing bought

- John bought **the car** at the dealership
- **The car** was bought by John
- John's purchase of **the car**
- The sale of **the car** cleared their inventory.

Semantic Frame

APPLY_HEAT

- Lexical units:

bake.v, barbecue.v, blanch.v, boil.v, braise.v, broil.v, brown.v, char.v, coddle.v, cook.v, deep fry.v, fry.v, grill.v, microwave.v, parboil.v, plank.v, poach.v, roast.v, saute.v, scald.v, sear.v, simmer.v, singe.v, steam.v, steep.v, stew.v, toast.v

- Core Frame Elements:

Cook	The Cook applies heat to the Food.
Food	Food is the entity to which heat is applied by the Cook.
Heating instrument	The entity that directly supplies heat to the Foo
Container	The Container holds the Food to which heat is applied.
Temperature setting	The Temperature_setting of the Heating_instrument for the Food.

Semantic Frame

DESTROY

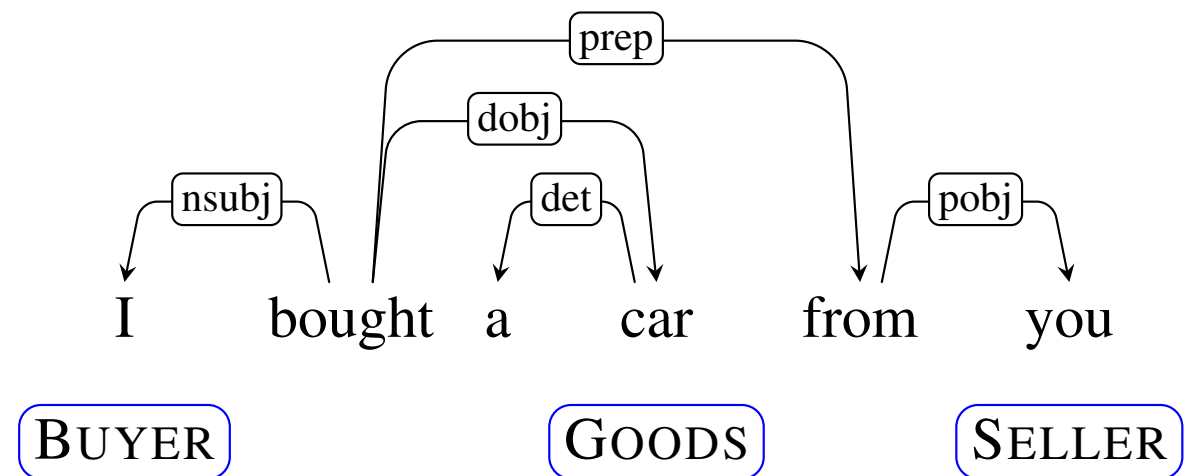
- Lexical units:

annihilate.v, annihilation.n, blast.v, blow up.v, demolish.v, demolition.n, destroy.v, destruction.n, destructive.a, devastate.v, devastation.n, dismantle.v, dismantlement.n, lay waste.v, level.v, obliterate.v, obliteration.n, raze.v, ruin.v, take out.v, unmake.v, vaporize.v

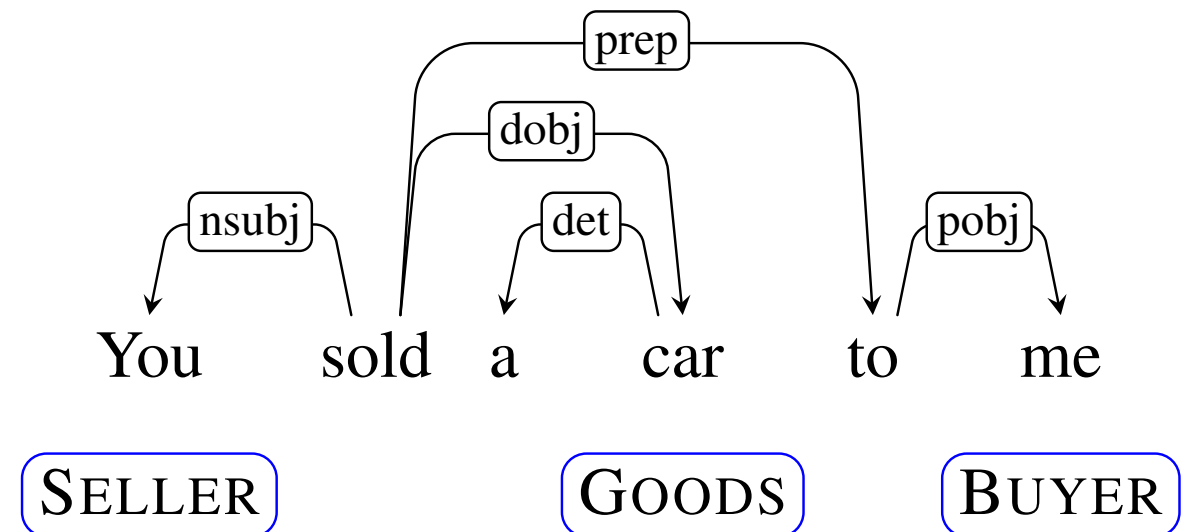
- Core Frame Elements:

Cause	The event or entity which is responsible for the destruction of the Patient.
Destroyer	The conscious entity, generally a person, that performs the intentional action that results in the Patient's destruction.
Patient	The entity which is destroyed by the Destroyer.

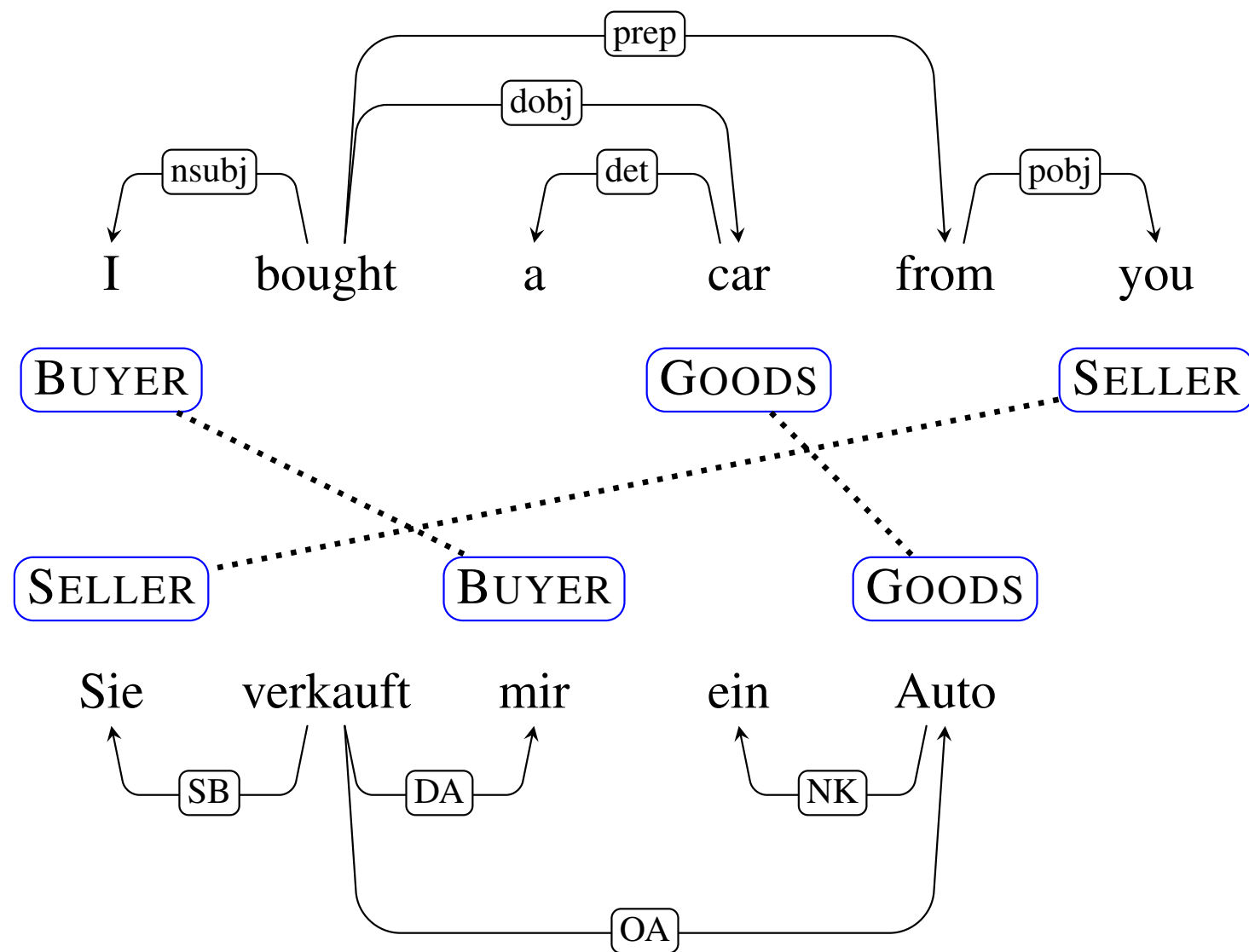
Semantic representations



Two different
perspectives on a
commercial transaction



Multilingual frames



Multilingual frames

- French
- Chinese
- Brazilian Portuguese
- German
- Spanish
- Japanese
- Swedish
- Korean

https://framenet.icsi.berkeley.edu/fndrupal/framenets_in_other_languages

Semantic role labeling

- Input: a sentence
- Output:
 - A list of predicates, each containing:
 - a label (e.g., Framenet frame)
 - a span
 - a set of arguments, each containing:
 - a label (thematic role, FrameNet role)
 - a span

Semantic role labeling

FrameNet

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

PropBank

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

How would we do this?