CS447: Natural Language Processing

http://courses.engr.illinois.edu/cs447

Lecture 21: Verb Semantics (I)

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Where we're at

Last lecture: Compositional semantics

Today: Verb semantics

— Argument structure and Thematic/Semantic roles

— Verb classes

— Semantic Role Labeling (briefly)

(Chapter 20 in textbook)

What do nouns and verbs mean?

In the simplest case, an NP is just a name:

John, Urbana, USA, Thanksgiving,

Names refer to (real or abstract) entities in the world.

Verbs define n-ary predicates:

stand, run, eat, win,

Depending on the arguments they take (and the state of the world), the proposition that is obtained when we apply these predicates to the arguments can be true or false in a given situation.

What do sentences mean?

Declarative sentences (statements) can be true or false, depending on the state of the world:

John sleeps.

In the simplest case, they consist of a verb and one or more noun phrase arguments.

Principle of compositionality (Frege):

The meaning of an expression depends on the meaning of its parts and how they are put together.

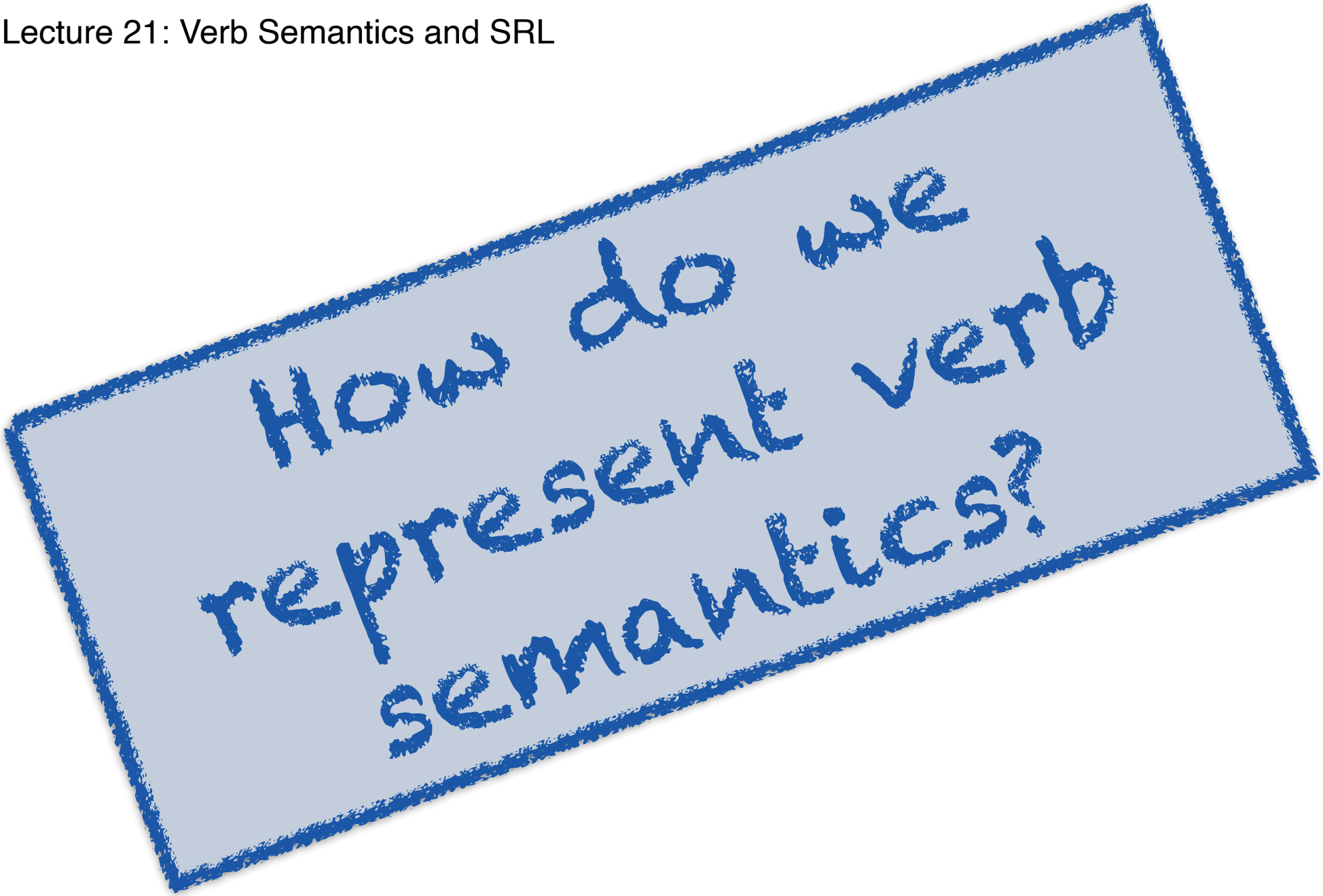
Using FOL to represent meaning

John is a student:
$student(john')$

All students take at least one class:
$\forall x\ student(x) \rightarrow \exists y(class(y) \wedge take(x,y))$

There is a class that all students take:
$\exists y(class(y) \wedge \forall x\ (student(x) \rightarrow take(x,y))$

John loves Mary
$love(john', mary')$

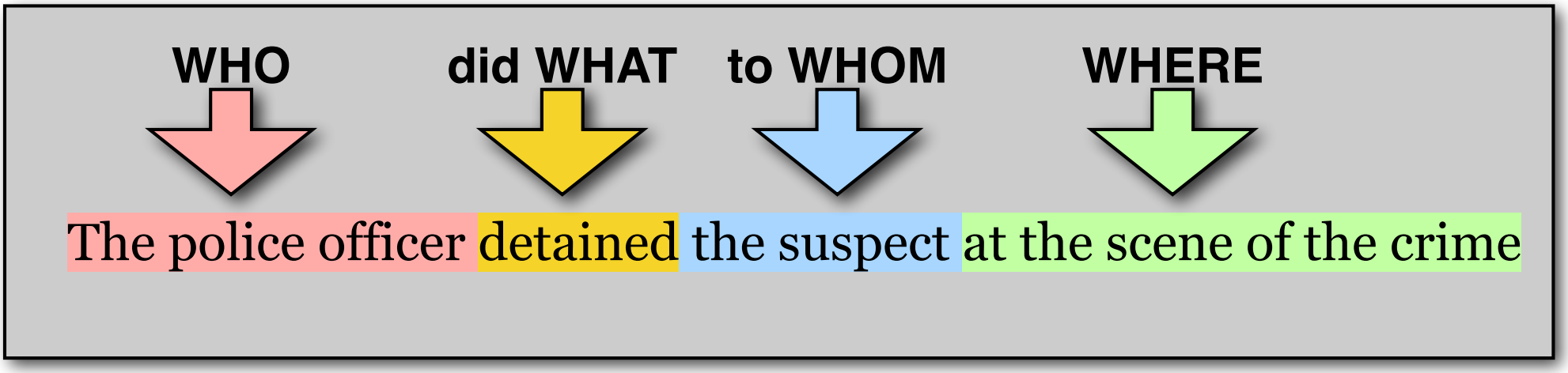

How do we
represent verb
semantics?

Predicate-argument structure

Understanding a sentence = knowing who did what (to whom, when, where, why…)

Verbs corresponds to predicates (what was done)

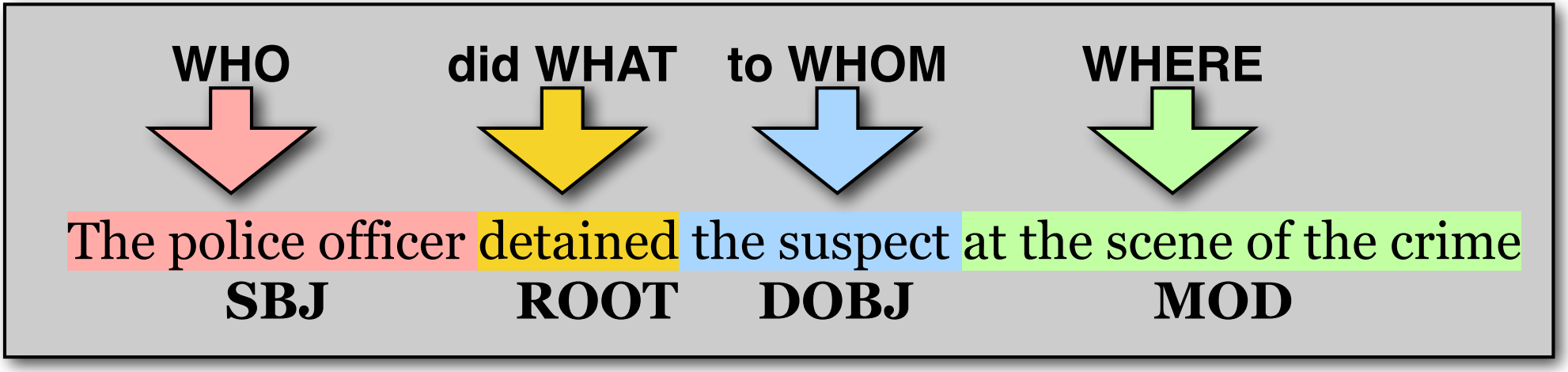
Their **arguments** (and modifiers) identify who did it, to whom, where, when, why, etc.



Syntactic Parsing

Syntactic Parsing (e.g. dependency parsing) identifies **grammatical roles** (subject, object, etc.)

But grammatical roles do not uniquely identify semantic roles…



What do verbs mean?

Verbs describe **events** or **states** ('eventualities'):

Tom broke the window with a rock.

The window broke.

The window was broken by Tom/by a rock.

If we *naively* translate verbs to **(logical) predicates…**

(subject = first argument, object = second argument, etc.)

```
break(Tom, window, rock)
break(window)
break(window, Tom)
break(window, rock)
```

… we don't really capture that these sentences describe the same event.

There are many different ways to describe the same event

Grammatical roles ≠ Semantic roles

Tom **broke the window** with a rock.

The window broke.

The window was broken by Tom/by a rock.

Related verbs/nouns can describe the same event:

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…

Can we map sentences describing the same event to **the same representation?**

Neo-Davidsonian Event Representations

Predicate logic with explicit **event variables** e, and explicit **predicates for each role**:

Sasha broke the window

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

Pat opened the door

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

Explicit event variables make it easy to add **adjuncts** ($\text{Time}(e, t)$), and to express **relations between events**.

But *verb-specific* roles (Breaker and Opener) are hard to reason about/with or to generalize across verbs.

Towards Thematic roles

Breaker and Opener have something in common!

- Both are volitional actors
- Both are often animate
- Both bear a direct causal responsibility for the event

Thematic roles are a way to capture the semantic commonality between the Breaker and Opener.

The Breaker and Opener are both AGENTS.

The BrokenThing and OpenedThing are THEMES.

(THEME: Prototypically inanimate objects affected in some way by the action)

Semantic/Thematic roles

Verbs describe **events** or **states** ('eventualities'):

Tom broke the window with a rock.

The window broke.

The window was broken by Tom/by a rock.

Thematic roles refer to **participants** of these events:

Agent (who performed the action): Tom

Patient (who was the action performed on): window

Tool/Instrument (what was used to perform the action): rock

Semantic/thematic roles (agent, patient) are different from **grammatical roles** (subject or object).

Thematic roles

One of the oldest linguistic concepts

- 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 later to the term *case*

Thematic grid, case frame, θ-grid

Tom broke the **window** with a **rock**.
The **window broke**.
The **window was broken** by **Tom**
The **window was broken** by a **rock**.

Tom: AGENT
window: THEME
rock: INSTRUMENT

A **thematic grid (case frame, θ-grid)** identifies the **set of semantic / thematic roles** associated with a particular **event type**:

BREAK: AGENT, THEME, INSTRUMENT

Each of these semantic/thematic roles can be expressed **('realized')** by different grammatical roles:

AGENT/Subject THEME/Object INSTRUMENT/PP$_{with}$.
THEME/Subject.
THEME/PassSubject AGENT/PP$_{by}$
THEME/PassSubject INSTRUMENT/PP$_{by}$

The inventory of thematic roles

To create systems that can identify thematic roles automatically, we need to create labeled training data.

This means we need to define an inventory of thematic roles

It is difficult to give a formal definition of thematic roles that generalizes across all verbs.

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*.

Problems with Thematic Roles

Hard to create a standard set of roles
or formally define them

Often roles need to be fragmented to be defined, e.g.:

Levin and Rappaport Hovav (2015): two kinds of INSTRUMENTS

Intermediary instruments can appear as subjects

The cook **opened** the jar **with the new gadget**.

The new gadget opened the jar.

Enabling instruments cannot appear as subjects:

Shelly **ate** the sliced banana **with a fork**.

***The fork ate** the sliced banana.

Alternatives to thematic roles

Fewer roles:

Generalized semantic roles,
defined as prototypes (Dowty 1991)

- PROTO-AGENT
- PROTO-PATIENT
- PropBank: Generic roles with frame-specific interpretation

More roles:

Specific roles that belong only specific predicates

- FrameNet: Frame-specific roles

Diathesis Alternations

Active/passive alternation:

Tom **broke** the window with a rock. (active voice)

The window **was broken** by Tom/by a rock. (passive voice)

Causative alternation:

Tom **broke** the window. ('causative'; active voice)

The window **broke**. ('anticausative'/'inchoative'; active voice)

Dative alternation:

Tom **gave** the gift to Mary.

Tom **gave** Mary the gift.

Locative alternation:

Jessica **loaded** **boxes** into **the wagon**.

Jessica **loaded** **the wagon** with **boxes**.

Verb classes ("Levin classes")

Verbs with similar meanings undergo the same syntactic alternations, and have the same set of thematic roles (Beth Levin, 1993)

VerbNet (verbs.colorado.edu; Kipper et al., 2008)

A large database of verbs, their thematic roles and their alternations (linked to Propbank and FrameNet style frame files: https://uvi.colorado.edu)

Corpora for Verb Semantics: Semantic Role Labeling

FrameNet

Baker et al. 1998, Fillmore et al. 2003, Fillmore and Baker 2009, Ruppenhofer et al. 2006

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

A **FrameNet frame** defines a set of **frame-specific semantic roles** (called **frame elements**), and includes a set of **predicates** (e.g verbs) that take these roles.

It also includes **example sentences** (not shown below)

Frame: `Change-position-on-a-scale`
Predicates: rise, increase,…
Frame Elements: ITEM, ATTRIBUTE, INITIAL VALUE, FINAL VALUE
This frame consists of words that indicate the change of an ITEM's position on a scale (the ATTRIBUTE) from a starting point (INITIAL VALUE) to an end point (FINAL VALUE)

The "Change position on a scale" Frame

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	

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.

Proposition Bank (PropBank)

Palmer, Martha, Daniel Gildea, and Paul Kingsbury. 2005. *Computational Linguistics*, 31(1):71–106

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

Penn Treebank annotated with semantic roles
and frame files for English verbs

Very coarse numbered argument roles (arg0, arg1,…),
used for all verbs (but interpretation depends on specific verb),
(inspired by Dowty 1991's proto-roles)

Arg0 = proto-agent

Arg1 = proto-patient

Arg2...: specific to each verb

ArgM-TMP/LOC/...: temporal/locative/... modifiers

PropBank Frames and Annotations

agree.01 Arg0: Agreer Arg1: Proposition
Arg2: Other entity agreeing

[Arg0 The group] agreed [Arg1 it wouldn't make an offer]
[Arg0 John] agrees with [Arg2 Mary]

fall.01 Arg1: patient/thing falling Arg2: extent/amount fallen
Arg3: start point Arg4: end point

[Arg1 Sales] fell [Arg4 to $251 million]
[Arg1 Junk bonds] fell [Arg2 by 5%]

Core PropBank roles

Proto-Agent (ARG0)

- 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 (ARG1)

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

Modifier roles: Arg-M-…

ARG-M-TMP: temporal (when?)

yesterday evening, now, last year

ARG-M-LOC: locative (where?)

at the museum, in San Francisco

ARG-M-DIR: directional (where to/from?)

down, to Bangkok

ARG-M-MNR: manner (how?)

clearly, with much enthusiasm

ARG-M-PRP/CAU: purpose/cause (why?)

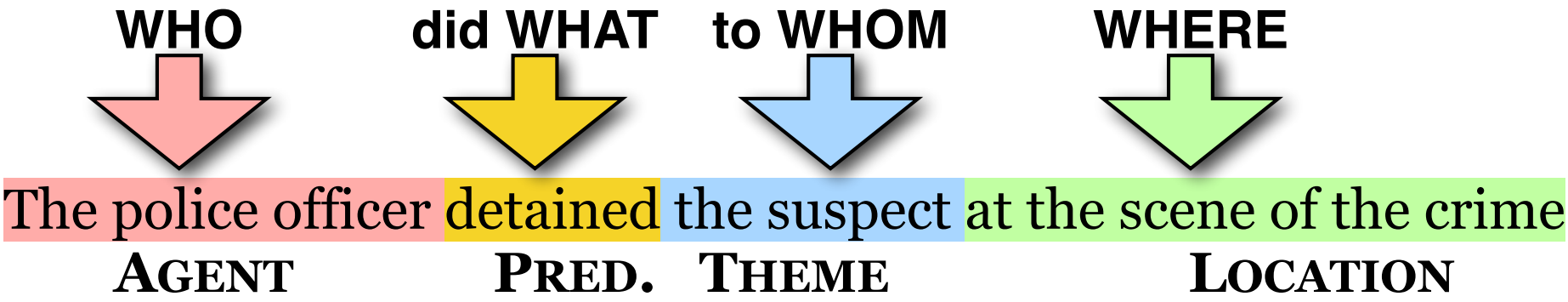
because…, in order to, …

ARG-M-PRD secondary predication

eat the meat *raw*

ARG-M-ADV miscellaneous other adverbs

Semantic Role Labeling (SRL)



The task of identifying…

— all **predicates** in a sentence

— the **arguments of each predicate** and their **semantic role**

SRL systems for English are typically trained on **PropBank** or **FrameNet**

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)

SRL algorithms

Syntactic (phrase-structure) parsing has often been seen as a prerequisite for SRL:

- Arguments (typically) correspond to syntactic constituents.
- Semantic roles depend often on the grammatical relations between the predicate and its arguments
  (modeling this may require features that capture the path in the tree between the argument and the predicate)

SRL can also be viewed as a **sequence-labeling** task: For each predicate, identify the spans of each argument.