Lecture 21: Semantic Role Labeling and Verb Semantics

Julia Hockenmaier

juliahmr@illinois.edu
3324 Siebel Center
Part 1: How do we represent verb semantics?
Where we’re at

Last lecture: Lexical semantics, mostly for nouns
— Sense relations (e.g. hypernym/hyponym relations)
— Word Sense Disambiguation

Today: Verb semantics
— Argument structure and Thematic/Semantic roles
— Verb classes
— Semantic Role Labeling (briefly)
(Chapter 20 in textbook)
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.

The police officer **detained** the suspect **at the scene of the crime**
**Syntactic Parsing**

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

But grammatical roles do not uniquely identify semantic roles…

![Diagram showing the roles and the sentence: The police officer detained the suspect at the scene of the crime.](image)
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?
Explicit event variables make it easy to add **adjuncts** (\(\text{Time}(e, t)\)), and to express **relations between events**.

But **verb-specific** roles (\(\text{Breaker}\) and \(\text{Opener}\)) 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.

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**
**THEME/Subj ect.**
**THEME/PassSubject** AGENT/PP
**THEME/PassSubject** INSTRUMENT/PP

Tom: AGENT
window: THEME
rock: INSTRUMENT
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:

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

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

<table>
<thead>
<tr>
<th>VERBS:</th>
<th>dwindling</th>
<th>move</th>
<th>soar</th>
<th>escalation</th>
<th>shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>advance</td>
<td>edge</td>
<td>mushroom</td>
<td>swell</td>
<td>explosion</td>
<td>tumble</td>
</tr>
<tr>
<td>climb</td>
<td>explode</td>
<td>plummet</td>
<td>swing</td>
<td>fall</td>
<td></td>
</tr>
<tr>
<td>decline</td>
<td>fall</td>
<td>reach</td>
<td>triple</td>
<td>fluctuation</td>
<td>gain</td>
</tr>
<tr>
<td>decrease</td>
<td>fluctuate</td>
<td>rise</td>
<td>tumble</td>
<td></td>
<td>hike</td>
</tr>
<tr>
<td>diminish</td>
<td>gain</td>
<td>rocket</td>
<td>shift</td>
<td></td>
<td>increase</td>
</tr>
<tr>
<td>dip</td>
<td>grow</td>
<td>skyrocket</td>
<td>slide</td>
<td></td>
<td>rise</td>
</tr>
<tr>
<td>double</td>
<td>increase</td>
<td>jump</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>drop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADVERBS:</th>
<th>increasingly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOUNS:</th>
<th>decline</th>
<th>decrease</th>
<th>growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>increase</td>
<td>rise</td>
<td></td>
</tr>
</tbody>
</table>

### Core Roles

<table>
<thead>
<tr>
<th>Role</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATTRIBUTE</td>
<td>The ATTRIBUTE is a scalar property that the ITEM possesses.</td>
</tr>
<tr>
<td>DIFFERENCE</td>
<td>The distance by which an ITEM changes its position on the scale.</td>
</tr>
<tr>
<td>FINAL_STATE</td>
<td>A description that presents the ITEM’s state after the change in the ATTRIBUTE’s value as an independent predication.</td>
</tr>
<tr>
<td>FINAL_VALUE</td>
<td>The position on the scale where the ITEM ends up.</td>
</tr>
<tr>
<td>INITIAL_STATE</td>
<td>A description that presents the ITEM’s state before the change in the ATTRIBUTE’s value as an independent predication.</td>
</tr>
<tr>
<td>INITIAL_VALUE</td>
<td>The initial position on the scale from which the ITEM moves away.</td>
</tr>
<tr>
<td>ITEM</td>
<td>The entity that has a position on the scale.</td>
</tr>
<tr>
<td>VALUE_RANGE</td>
<td>A portion of the scale, typically identified by its end points, along which the values of the ATTRIBUTE fluctuate.</td>
</tr>
</tbody>
</table>

### Some Non-Core Roles

<table>
<thead>
<tr>
<th>Role</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>DURATION</td>
<td>The length of time over which the change takes place.</td>
</tr>
<tr>
<td>SPEED</td>
<td>The rate of change of the VALUE.</td>
</tr>
<tr>
<td>GROUP</td>
<td>The GROUP in which an ITEM changes the value of an ATTRIBUTE in a specified way.</td>
</tr>
</tbody>
</table>
Proposition Bank (PropBank)


[The San Francisco Examiner] issued [a special edition] [yesterday]

<table>
<thead>
<tr>
<th>ARG0</th>
<th>TARGET ARG1</th>
<th>ARGM-TMP</th>
</tr>
</thead>
</table>

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
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.