The police officer detained the suspect at the scene of the crime

Semantic Role Labeling

Who did what to whom at where?

The police officer detained the suspect at the scene of the crime

Agent Predicate Theme Location
Can we figure out that these have the same meaning?

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...

A Shallow Semantic Representation:
Semantic Roles

Predicates (bought, sold, purchase) represent an event and semantic roles express the abstract role that arguments of a predicate can take in the event

More specific: buyer

More general: proto-agent

Agent
Getting to semantic roles

What roles are involved in a breaking event?

First order logic event representation for Sasha broke the window:

\[ \exists e, x, y \text{Breaking}(e) \land \text{Breaker}(e, \text{Sasha}) \land \text{BrokenThing}(e, y) \land \text{Window}(y) \]

\[ \exists e, x, y \text{Opening}(e) \land \text{Opener}(e, \text{Pat}) \land \text{OpenedThing}(e, y) \land \text{Door}(y) \]

Subjects of break and open: **Breaker** and **Opener**

**Deep roles** specific to each event (breaking, opening)

Hard to reason about them for NLU applications like QA
Thematic roles

- **Breaker** and **Opener** have something in common!
  - Volitional actors
  - Often animate
  - Direct causal responsibility for their events
- Thematic roles are a way to capture this semantic commonality between *Breakers* and *Openers*.
- They are both AGENTS.
- The *BrokenThing* and *OpenedThing*, are THEMES.
  - prototypically inanimate objects affected in some way by the action

---

Thematic roles

- One of the oldest linguistic models
  - 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 to the term *case*
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 cause of an event</td>
<td><em>The waiter spilled the soup.</em></td>
</tr>
<tr>
<td>EXPERIENCER</td>
<td>The experiencer of an event</td>
<td><em>John has a headache.</em></td>
</tr>
<tr>
<td>FORCE</td>
<td>The non-volitional cause of the event</td>
<td><em>The wind blows debris from the mall into our yards.</em></td>
</tr>
<tr>
<td>THEME</td>
<td>The participant most directly affected by an event</td>
<td><em>Only after Benjamin Franklin broke 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><em>Mona asked “You met Mary Ann at a supermarket?”</em></td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>An instrument used in an event</td>
<td><em>He poached catfish, stunning them with a shocking device...</em></td>
</tr>
<tr>
<td>BENEFICIARY</td>
<td>The beneficiary of an event</td>
<td><em>Whenever Ann Callahan makes hotel reservations for her boss...</em></td>
</tr>
<tr>
<td>SOURCE</td>
<td>The origin of the object of a transfer event</td>
<td><em>I flew in from Boston.</em></td>
</tr>
<tr>
<td>GOAL</td>
<td>The destination of an object of a transfer event</td>
<td><em>I drove to Portland.</em></td>
</tr>
</tbody>
</table>

Thematic grid, case frame

Example usages of “break”

- John broke the window
- John broke the window with a rock
- The rock broke the window
- The window broke
- The window was broken by John
Thematic grid, case frame

Example usages of “break”

John broke the window.
AGENT THEME

John broke the window with a rock.
AGENT THEME INSTRUMENT

The rock broke the window.
INSTRUMENT THEME

The window broke.
THEME

The window was broken by John.
THEME AGENT
Diathesis alternations (or verb alternation)

*Doris* gave the book to Cary.  
**Break:** AGENT, INSTRUMENT, or THEME as subject  
*Doris* gave Cary the book.  
**Give:** THEME and GOAL in either order  

**Dative alternation:** particular semantic classes of verbs like *give*, “verbs of future having” (*advance, allocate, offer, owe*), “send verbs” (*forward, hand, mail*), “verbs of throwing” (*kick, pass, throw*), etc.

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Problems with Thematic Roles

Hard to create standard set of roles or formally define them  
Often roles need to be fragmented to be defined.

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

**intermediary instruments** that can appear as subjects

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

**enabling instruments** that cannot

Shelly ate the sliced banana with a fork.  
*The fork ate the sliced banana.*
Alternatives to thematic roles

1. **Fewer roles**: generalized semantic roles, defined as prototypes (Dowty 1991)
   PROTO-AGENT
   PROTO-PATIENT
   PropBank

2. **More roles**: Define roles specific to a group of predicates
   FrameNet

---

PropBank

- [http://verbs.colorado.edu/~mpalmer/projects/ace.html](http://verbs.colorado.edu/~mpalmer/projects/ace.html)
PropBank Roles

Following Dowty 1991

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

• Following Dowty 1991
  • Role definitions determined verb by verb, with respect to the other roles
  • Semantic roles in PropBank are thus verb-sense specific.

• Each verb sense has numbered argument: Arg0, Arg1, Arg2,...
  Arg0: PROTO-AGENT
  Arg1: PROTO-PATIENT
  Arg2: usually: benefactive, instrument, attribute, or end state
  Arg3: usually: start point, benefactive, instrument, or attribute
  Arg4: the end point

(Arg2-Arg5 are not really that consistent, causes a problem for labeling)
Advantage of a PropBank Labeling

increase.01 “go up incrementally”
Arg0: causer of increase
Arg1: thing increasing
Arg2: amount increased by, EXT, or MNR
Arg3: start point
Arg4: end point

This would allow us to see the commonalities in these 3 sentences:

Big Fruit Co. increased the price of bananas.
The price of bananas was increased again by Big Fruit Co.
The price of bananas increased 5%
Advantage of a ProbBank Labeling

- increase.<sub>01</sub> “go up incrementally”
  - Arg0: causer of increase
  - Arg1: thing increasing
  - Arg2: amount increased by, EXT, or MNR
  - Arg3: start point
  - Arg4: end point

This would allow us to see the commonalities in these 3 sentences:

- [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%].

Modifiers or adjuncts of the predicate: Arg-M

<table>
<thead>
<tr>
<th>ArgM-TMP</th>
<th>LOC</th>
<th>DIR</th>
<th>MNR</th>
<th>PRP/CAU</th>
<th>REC</th>
<th>ADV</th>
<th>PRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>yesterday evening, now</td>
<td>at the museum, in San Francisco</td>
<td>down, to Bangkok</td>
<td>clearly, with much enthusiasm</td>
<td>because ... , in response to the ruling</td>
<td>themselves, each other</td>
<td>...ate the meat raw</td>
<td></td>
</tr>
</tbody>
</table>
Analysts have been expecting a GM-Jaguar pact that would give the U.S. car maker an eventual 30% stake in the British company.

The same parse tree PropBanked

propbanking a sentence

s

have been expecting

(Analysts)

have

been

expecting

a GM-Jaguar pact

that would give the US car maker an eventual 30% stake in the British company

expect(Analysts, GM-J pact)
give(GM-J pact, US car maker, 30% stake)
Annotated PropBank Data

- Penn English TreeBank, OntoNotes 5.0.
  - Total ~2 million words
- Penn Chinese TreeBank
- Hindi/Urdu PropBank
- Arabic PropBank

2013 Verb Frames Coverage
Count of word sense (lexical units)

<table>
<thead>
<tr>
<th>Language</th>
<th>Final Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>10,615*</td>
</tr>
<tr>
<td>Chinese</td>
<td>24,642</td>
</tr>
<tr>
<td>Arabic</td>
<td>7,015</td>
</tr>
</tbody>
</table>

From Martha Palmer 2013 Tutorial

Capturing descriptions of the same event by different nouns/verbs

[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

• Roles in PropBank are specific to a verb
• Role in FrameNet are specific to a frame: a background knowledge structure that defines a set of frame-specific semantic roles, called frame elements,
  • includes a set of predicates that use these roles
  • each word evokes a frame and profiles some aspect of the frame

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

The “Change position on a scale” Frame

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)

[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...
### 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:
- gain
- increasingly
diminish
- gain
- rocket
dip
- grow
- shift
- NOUNS:
- hike
double
- increase
- skyrocket
drop
- jump
- slide
- decrease
- rise

---

### The “Change position on a scale” Frame

<table>
<thead>
<tr>
<th>Core Roles</th>
<th></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>

<table>
<thead>
<tr>
<th>Some Non-Core Roles</th>
<th></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>
Relation 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:

“cause change position on a scale”
Is Causative of: Change_position_on_a_scale
Adds an agent Role

[AGENT They] raised [ITEM the price of their soda] [DIFFERENCE by 2%].
• add.v, crank.v, curtail.v, cut.n, cut.v, decrease.v, development.n, diminish.v, double.v, drop.v, enhance.v, growth.n, increase.v, knock down.v, lower.v, move.v, promote.v, push.n, push.v, raise.v, reduce.v, reduction.n, slash.v, step up.v, swell.v
Relations between frames

Schematic of Frame Semantics

Figure from Das et al 2010

Figure from Das et al (2014)
FrameNet and PropBank representations

In that time more than 1.2 million jobs have been created and the official jobless rate has been pushed below 37% from 23%.