Word Sense Ambiguity

Words that have multiple meanings are **polysemous**. Each meaning is called a **word sense**.

**Word sense disambiguation** is the problem of deciding which meaning a word has in a specific context.

I walked to the **bank**.
The water was inviting.
I needed to get cash.

She does not want to **run**.
Her ankle is still sore.
She is tired of politics.

The **table** looks good.
The legs are made of maple.
The numbers are strong.

He spotted the annoying **bug**.
Then it flew away.
He quickly fixed his code.

Random House College Dictionary has 93 definitions of the verb “take”!

1. to get into one’s hands by voluntary action (**take a book**)
2. to get into one’s hands by force (**take a bone from a dog**)
3. to catch (**to take a deer**)
4. to receive, react, or respond (**she took the news hard**)
5. to have for one’s benefit or use (**take a nap or take a bath**)
6. to enter into the enjoyment of (recreation) (**take a vacation**)
7. to end a life (**he took his own life**)
8. to subtract or deduct (**if you take 3 from 5, that leaves 2**)
9. to convey or transport (**we took the kids for a ride**)
10. to get over, through, or around (**he took the corner at top speed**)
11. to come upon suddenly (**take someone by surprise**)
12. to proceed to occupy (**take a seat**)
13. to make a picture or photograph (**he took home movies**)

And 9 definitions for the noun “take”

1. the act of taking
2. something that is taken
3. quantity of fish, game, etc. taken at one time
4. money taken in
5. a portion of copy assigned to a linotype operator (journalism)
6. a scene or portion of a scene (movies)
7. a recording of a musical performance
8. a successful inoculation (medicine)
9. in search of personal profit at the expense of others (**on the take**)

And verb + particle expressions

- **take after**
  
  She takes after her mother.

- **take down**
  
  The rocket took down a plane.

- **take back**
  
  I take back what I said.

- **take on**
  
  He took on the tobacco lobby.

- **take it out on**
  
  She took it out on her boyfriend.

- **take off**
  
  He took off for Bermuda.

- **take over**
  
  He plans to take over the company.

- **take to**
  
  The boy took to his new babysitter.

- **take up**
  
  The girl took up karate.

- **take up with**
  
  He took up with his neighbor.
Other forms of semantic ambiguity

- Quantifier scoping
  - *All of the cats caught a mouse*

- Collective vs. Distributive Interpretations
  - *The kids played baseball* → Collective
  - *The kids played solitaire* → Distributive

- Interactions between Syntax and Semantics
  - *I dislike long-haired dogs and cats.* → ambiguous
  - *I dislike long-haired dogs and birds.* → not ambiguous

Garden Path Effects

A garden path sentence is a sentence that most people initially interpret one way and then quickly change their interpretation.

- *The astronomer married a star.*
- *The musician composed himself.*
- *The old man the boat.*
- *The government plans to raise taxes were defeated.*
- *The horse raced past the barn fell.*

Semantic Roles

Different phrases in the same syntactic position can serve in different semantic roles.

- *John broke the window with the hammer.*
- *The hammer broke the window.*
- *The window broke.*
- *Rover smelled.*
- *Elvis smelled Rover.*
- *I ate the spaghetti with a fork.*
- *I ate the spaghetti with a friend.*
- *I ate the spaghetti with tomato sauce.*
- *I ate the spaghetti with glee.*

Thematic Roles

- **Thematic roles** (or thematic relations) represent the role that a noun phrase plays with respect to an action or state, usually expressed by a verb.

- Thematic roles are related to Charles Fillmore’s theory of case grammars and case roles.

- A relatively small set of thematic roles are commonly used, although there is no single definitive set.

- **Key Idea:** abstract away from syntax to represent the conceptual role that a phrase plays with respect to an action or state.

  *Different syntactic realizations of the same sentence should be represented with the same set of semantic roles!*
Common Thematic Roles

- Agent
- Theme
- Instrument
- Recipient
- Experiencer
- Beneficiary
- Cause
- Location
- Path

The Agent Role

- An **agent** is responsible for an action. Usually (though not always) this implies intentionality.

\[
\begin{align*}
\text{John broke the window.} \\
\text{John intentionally broke the window.}
\end{align*}
\]

- The agent is usually **ANIMATE**. Forces of nature (e.g., *tornado*) may be permissible agents if there is no **cause** role.

\[
\begin{align*}
\text{The hammer broke the window.} \\
\text{The hammer intentionally broke the window. (\*)}
\end{align*}
\]

- A **co-agent** is another entity that also performed the action.

\[
\begin{align*}
\text{John painted the wall with Mary.}
\end{align*}
\]

The Theme Role

- The **theme** (or **patient**) is the thing being affected or acted upon.

\[
\begin{align*}
\text{Rover smelled.} \\
\text{John smelled Rover.} \\
\text{John gave Rover a bath.}
\end{align*}
\]

- The theme is usually the answer to the question: “What was verb-ed?”

- A **co-theme** is another object/concept that is affected or acted upon.

\[
\begin{align*}
\text{John washed Rover along with Snoopy.}
\end{align*}
\]

The Instrument Role

An **instrument** represents a tool, material, or force that is used to perform an action.

An instrument does not have to be a physical object. It can be anything used to accomplish an action.

\[
\begin{align*}
\text{The hammer broke the window.} \\
\text{I ate spaghetti with a fork.} \\
\text{I saw Elvis with binoculars.} \\
\text{He paid for the repair using his credit card.} \\
\text{He used a telescope to see Elvis.} \\
\text{John broke the door down with his weight.}
\end{align*}
\]
The Recipient and Beneficiary Roles

• The **recipient** role is assigned to an entity that receives something.
  – John gave a birthday present to Mary.
  – John gave Mary a birthday present.

• The **beneficiary** role is assigned to an entity that benefits from an action (without receiving anything).
  – John sang a song for Mary.
  – John sang Mary a song.

The Experiencer and Cause Roles

• Some verbs express internal beliefs, emotions, or states. The **experiencer** role represents an entity who is experiencing something.
  – Mary believes that Elvis is still alive.
  – The boy fears spiders.

• A **cause** role is sometimes used for events or situations that produce an effect.
  – The economic recession led to many corporate layoffs.
  – The tornado damaged thousands of homes.

Locations, Times, Measurements

**Location, Time, and Measurement** roles may be subdivided into subroles representing different types of state changes.

**AT State:** Yosemite is in California. → AT-LOC
  I woke up at 7am. → AT-TIME
  I have 20 dollars. → AT-VALUE

**FROM/TO Change:**
  I drove from Utah to California. → FROM-LOC (Origin/Source)
  TO-LOC (Destination)
  The party starts at 8pm and ends at midnight. → FROM-TIME
  TO-TIME

**PATH:** a trajectory
  She swam across the channel. → PATH-LOC

Semantic Frames

• A **semantic frame** (or *case frame*) is a conceptual structure that represents the semantic arguments of a word (usually a verb). They originated from Charles Fillmore’s theory of **frame semantics**.

• A frame represents semantic knowledge about an activity or state that captures its meaning.

• In semantics, predicates take **arguments**, which are necessary to represent the meaning of an activity or state described in text. (They are similar to **complements** in syntax.)
  Examples: agents, themes, recipients

• In contrast, **adjuncts** are optional. They are not needed to complete the meaning of the predicate.
  Examples: dates, locations, manner
Case Frame Representations

Case frames can be defined manually with mappings between syntactic and semantic roles. For example:

GAVE
Agent = subject
Theme = direct object
Recipient = indirect object

```
John gave Mary a book.
```

John was killed by Mary.

KILLED
Theme = John
Agent = Mary

John was killed by a bomb.

GAVE
Theme = John
Co-Theme = Mary
Agent = a man
Instrument = a bomb

Selectional Restrictions

Semantic constraints called **selectational restrictions** can be assigned to semantic roles for disambiguation.

GAVE
Agent = subject [ANIMATE]
Theme = direct object [PHYSOBJ]
Recipient = indirect object [ANIMATE]

```
John gave Mary a book.
```

```
John gave Mary a book.
```

Case Frame Example

```
John was killed by Mary.
```

KILLED
Theme = John
Agent = Mary

```
John was killed with Mary by a man with a bomb.
```

GAVE
Theme = John
Co-Theme = Mary
Agent = a man
Instrument = a bomb

Another Example

EAT (Active)
Agent = subject [ANIMATE]
Theme = direct object [FOOD]
Instrument = PP(with) [UTENSIL]
Co-Theme = PP(with) [FOOD]
Co-Agent = PP(with) [ANIMATE]

```
Tom ate pizza with pepperoni.
```

EAT
Agent = Tom
Theme = pizza
Instrument = fork

```
Tom ate pizza with pepperoni with a fork with Jane.
```

EAT
Agent = Tom
Theme = pizza
Co-Theme = pepperoni
Instrument = fork
Co-Agent = Jane

```
Tom ate pizza with Jane.
```

EAT
Agent = Tom
Theme = pizza
Co-Agent = Jane
Semantic Role Labeling

- Semantic Role Labeling (SRL) is a NLP task that involves automatically assigning semantic roles to the words and phrases in a sentence.
- Semantic roles are always relative to a target word, which is usually a verb. A phrase can sometimes serve in multiple semantic roles for different target words in the same sentence.
- SRL systems typically use machine learning to automatically produce semantic role assignments.
- Framenet and PropBank are two SRL resources that used different frame definitions and semantic role representations. They include manually annotated data sets that are widely used for training and evaluation.

FrameNet

- The Berkeley FrameNet project is an effort to create frame-semantic descriptions for English terms.
- A frame is a conceptual structure describing the argument structure for lexical items, and frame elements (FEs) are the semantic roles for a frame.
- FrameNet includes a lexical resource that consists of a frame database that defines frames and their conceptual structure, a dictionary of semantic frames associated with words (lexical units), and annotated example sentences.

Frame Examples

\[
\begin{array}{l}
\text{frame(TRANSPORTATION)} \\
\quad \text{frame}_\text{elements}(\text{MOVER, MEANS, PATH}) \\
\quad \text{scene}(\text{MOVER move along PATH by MEANS}) \\
\end{array}
\]

\[
\begin{array}{l}
\text{frame(DRIVING)} \\
\quad \text{inherit(TRANSPORTATION)} \\
\quad \text{frame}_\text{elements}(\text{DRIVER (=MOVER), VEHICLE (=MEANS), RIDER (=MOVER), CARGO (=MOVER)}) \\
\quad \text{scenes}(\text{DRIVER starts VEHICLE, DRIVER controls VEHICLE, DRIVER stops VEHICLE}) \\
\end{array}
\]

\[
\begin{array}{l}
\text{frame(RIDING)} \\
\quad \text{inherit(TRANSPORTATION)} \\
\quad \text{frame}_\text{elements}(\text{VEHICLE (=MEANS), RIDER (=MOVER)}) \\
\quad \text{scenes}(\text{RIDER enters VEHICLE, VEHICLE carries RIDER along PATH, RIDER leaves VEHICLE}) \\
\end{array}
\]

Frame Element Annotations

- Kate\text{\textsuperscript{driver}} drove home\text{\textsuperscript{path}} in a stupor.
- A woman fell into the path of [a car]\text{\textsuperscript{vehicle}} driven by [her uncle]\text{\textsuperscript{driver}}.
- And that is why Tom\text{\textsuperscript{driver}} drove [eastwards along Lake Geneva]\text{\textsuperscript{path}}.
- [John Smith]\text{\textsuperscript{driver}} was driving [his guest]\text{\textsuperscript{rider}} [back to the station]\text{\textsuperscript{path}}.
- Susan\text{\textsuperscript{driver}} drove [her Honda]\text{\textsuperscript{vehicle}} at high speed [around the streets of Utah]\text{\textsuperscript{path}}.
- We\text{\textsuperscript{driver}} drive [home along miles of empty freeway]\text{\textsuperscript{path}}.
More Examples

• Pat replaced [the curtains]_{OLD} with [wooden blinds]_{NEW}.
• Boil [the rice]_{FOOD} [for 3 minutes]_{DURATION} [in water]_{MEDIUM}, then drain.
• [Four activists]_{AGENT} chained [themselves]_{ITEM} [to an oil drilling rig being towed to the Bering Sea]_{GOAL}.
• She \textit{blames} [the government]_{EVALUEE} [for not doing enough]_{REASON}.
• The government claims that ranchers \textit{misrepresent} their livestock losses and \textit{blame} everything [on coyotes]_{EVALUEE}.

\textbf{Commerce\_sell}

\textbf{Definition:}
These are words describing basic commercial transactions involving a buyer and a seller exchanging money and goods, taking the perspective of the seller. The words vary individually in the patterns of frame element realization they allow. For example, the typical patterns for \textit{SELLER sells} \textit{GOODS to BUYER for MONEY}:

- \textit{Robin sold} \textit{textbooks to Abby} for \$30.
- \textit{Kim sold} \textit{the sweater}.
- The \textit{buyer} has the \textit{money} and wants the \textit{good}.
- The \textit{seller} has possession of the \textit{good} and exchanges them for \textit{money} from a \textit{buyer}.
- So far, my company has \textit{sold} more than three million copies.

\textbf{Frame-frame Relations:}

Inherits from: \textit{Giving}
Is Inherited by: \textit{Buying_out}
Perspective on: \textit{Commerce\_goods-transfer}
Is Perspectivized in: \textit{Uses}
Is Used by: \textit{Carry\_goods, Exporting}
Subframe of: \textit{Sell\_x\_y}
Has Subframe(s):
  - \textit{Precedes:}
  - \textit{Is Preceded by:}
  - \textit{Is Inchoative of:}
  - \textit{Is Causative of:}
PropBank

- The PropBank project produced semantic role annotations on the Wall Street Journal portion of the Penn Treebank (which already had parse tree annotations).
- PropBank defines predicate-argument structures for verbs with semantic role assignments for each verb’s arguments.
- The predicate is labeled as REL (for relation) and is either a verb or a verb + particle (e.g., “keep up”).
- PropBank’s semantic role arguments are not named, but indicated as Arg0, Arg1, Arg2, etc. The meaning is specific to one verb sense! They do not have the same meaning for different verbs or different senses of the same verb.

PropBank Definitions

PropBank provides Frames files which defines a set of roles (roleset) for verb senses from VerbNet. There are two types of roles: numbered arguments and adjuncts.

Numbered Arguments: A0-A5
- Arg0 usually refers to the verb’s agent.
- Arg1 usually refers to the verb’s patient/theme (if it has one)
- All other arguments vary from verb to verb.

Adjuncts: optional, general arguments that any verb can take

PropBank Frame File Example

Frame File for the verb ‘expect’:

Roles:
Arg0: expecter
Arg1: thing expected

Example: Transitive, active:
Portfolio managers expect further declines in interest rates.

Arg0: Portfolio managers
REL: expect
Arg1: further declines in interest rates

PropBank Framesets

Different senses of a verb may have different semantic roles. In this case, framesets are used to define the semantic roles for each verb sense.

Example for the verb “left”:

Frameset leave.01 "move away from":
Arg0: entity leaving
Arg1: place left

Frameset leave.02 "give":
Arg0: giver
Arg1: thing given
Arg2: beneficiary
PropBank Examples

• [John]$_{ARG0}$ broke [the window]$_{ARG1}$.
• [The window]$_{ARG1}$ broke.
• [John]$_{ARG0}$ opened [the door]$_{ARG1}$ [with his foot]$_{ARG2}$.
• [John]$_{ARG0}$ tried to kick [the football]$_{ARG1}$.
• [He]$_{ARG0}$ expects [Ford to meet the deadline easily]$_{ARG1}$.
• [Mr. Bush]$_{ARG0}$ met [him]$_{ARG1}$ [privately]$_{ARGM-MNR}$ [in the White House]$_{ARGM-LOC}$ [on Thursday]$_{ARGM-TMP}$.
• [Sales]$_{ARG1}$ fell [to $50 million]$_{ARG4}$ [from $80 million]$_{ARG3}$.