Visier Info Session

Tues., Nov 3
12 – 1:30 pm
Kaiser 2020/2030

E-Portfolio Competition Info & Training Session

Wed., Nov 4
5:45 – 7:15 pm
DMP 310

Rakuten Info Session

Thurs., Nov 5
5:30 – 6:30 pm
DMP 110

Tri-mentoring/Townhall Event

Tues., Nov 10
5:45 – 7:30 pm
X860, ICICS/CS

Tableau Open House

Thurs., Nov 12
5 – 7 pm
http://waterviewvancouver.com
NLP Practical Goal for FOL: the ultimate Web question-answering system?

Map NL queries into FOPC so that answers can be effectively computed

What African countries are not on the Mediterranean Sea?

$$\exists c \text{ Country}(c) \land \neg \text{Borders}(c, \text{ Med. Sea}) \land \text{In}(c, \text{ Africa})$$

• Was 2007 the first El Nino year after 2001?

$$\text{ElNino}(2007) \land \neg \exists y \text{ Year}(y) \land \text{After}(y, 2001) \land \text{Before}(y, 2007) \land \text{ElNino}(y)$$
Just a sketch: to provide some context for some concepts / techniques discussed in 422
Logics in AI: Similar slide to the one for planning

Propositional Definite Clause Logics

Semantics and Proof Theory

Satisfiability Testing (SAT)

Production Systems

Ontologies

Cognitive Architectures

Semantic Web

Information Extraction

Video Games

Summarization

Tutoring Systems

Hardware Verification

Product Configuration

You will know a little Some Applications
Lecture Overview

- **Ontologies** – what objects/individuals should we represent? what relations (unary, binary,..)?
- Inspiration from **Natural Language**: WordNet and FrameNet
- Extensions based on Wikipedia and mining the Web (YAGO, ProBase, Freebase)
- Domain Specific Ontologies (e.g., Medicine: MeSH, UMLS)

Check interfaces for each of the above links on the course web page
Ontologies

Given a logical representation (e.g., FOL)
What individuals and relations are there and we need to model?

In AI an **Ontology** is a specification of what individuals and relationships are assumed to exist and what terminology is used for them

- What **types** of individuals
- What **properties** of the individuals
Ontologies: inspiration from Natural Language:

How do we refer to individuals and relationship in the world in NL e.g., English? words

Where do we find definitions for words? Dictionary

Most of the definitions are circular? They are descriptions. Red / B1009

Fortunately, there is still some useful semantic info (Lexical Relations):

- $w_1$ $w_2$ same Form and Sound, different Meaning Homonymy
- $w_1$ $w_2$ same Meaning, different Form Synonymy big/large
- $w_1$ $w_2$ “opposite” Meaning Antonymy good/bad
- $w_1$ $w_2$ Meaning$_1$, subclass of Meaning$_2$ Hyponymy dog/animal
Polysemy

Def. The case where we have a set of words with the same form and multiple related meanings.

Consider the homonym:

bank → commercial bank$^1$ vs. river bank$^2$

• Now consider: “A PCFG can be trained using derivation trees from a tree bank annotated by human experts”

• Is this a new independent sense of bank?
Synonyms

Def. Different words with the same meaning.

Substitutability - if they can be substituted for one another in *some* environment without changing meaning or acceptability.

Would I be flying on a large/big plane?

?... became kind of a large/big sister to...

? You made a large/big mistake
Hyponymy/Hypernym

Def. Pairings where one word denotes a sub/super class of the other

• Since dogs are canids
  ✓ Dog is a *hyponym* of canid and
  ✓ Canid is a *hypernym* of dog

  car/vehicle
  doctor/human
  ......
Lexical Resources

Databases containing all lexical relations among all words

- **Development:**
  - Mining info from dictionaries and thesauri
  - Handcrafting it from scratch

- **WordNet:** first developed with reasonable coverage and widely used, started with [Fellbaum… 1998]
  - for English (versions for other languages have been developed - see MultiWordNet)
WordNet 3.0

<table>
<thead>
<tr>
<th>Part Of Speech</th>
<th>Unique Strings</th>
<th>Word-Sense Pairs</th>
<th>Synsets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noun</td>
<td>117798</td>
<td>146312</td>
<td>82115</td>
</tr>
<tr>
<td>Verb</td>
<td>11529</td>
<td>25047</td>
<td>13767</td>
</tr>
<tr>
<td>Adjective</td>
<td>21479</td>
<td>30002</td>
<td>18156</td>
</tr>
<tr>
<td>Adverb</td>
<td>4481</td>
<td>5580</td>
<td>3621</td>
</tr>
<tr>
<td>Totals</td>
<td>155287</td>
<td>206941</td>
<td>117659</td>
</tr>
</tbody>
</table>

- For each word: all possible senses (no distinction between homonymy and polysemy)
- For each sense: a set of synonyms (synset) and a gloss
WordNet: entry for “table”

The noun "table" has 6 senses in WordNet.

1. table, tabular array -- (a set of data …)
2. table -- (a piece of furniture …)
3. table -- (a piece of furniture with tableware …)
4. mesa, table -- (flat tableland …)
5. table -- (a company of people …)
6. board, table -- (food or meals …)

The verb "table" has 1 sense in WordNet.

1. postpone, prorogue, hold over, put over, table, shelve, set back, defer, remit, put off -- (hold back to a later time; "let's postpone the exam")
## WordNet Relations (between synsets!)

<table>
<thead>
<tr>
<th>Relation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyponym</td>
<td>From concepts to subtypes</td>
<td><em>meat</em> → <em>beef</em></td>
</tr>
<tr>
<td>Hyponym</td>
<td>From concepts to subtypes</td>
<td><em>meat</em> → <em>beef</em></td>
</tr>
<tr>
<td>Has-Member</td>
<td>From groups to their members</td>
<td><em>faculty</em> → <em>professor</em></td>
</tr>
<tr>
<td>Member-Of</td>
<td>From members to their groups</td>
<td><em>copilot</em> → <em>crew</em></td>
</tr>
<tr>
<td>Has-Part</td>
<td>From wholes to parts</td>
<td><em>table</em> → <em>leg</em></td>
</tr>
<tr>
<td>Part-Of</td>
<td>From parts to wholes</td>
<td><em>course</em> → <em>meal</em></td>
</tr>
<tr>
<td>Antonym</td>
<td>Opposites</td>
<td><em>leader</em> → <em>follower</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyponym</td>
<td>From events to superordinate events</td>
<td><em>fly</em> → <em>travel</em></td>
</tr>
<tr>
<td>Troponym</td>
<td>From events to their subtypes</td>
<td><em>walk</em> → <em>stroll</em></td>
</tr>
<tr>
<td>Entails</td>
<td>From events to the events they entail</td>
<td><em>snore</em> → <em>sleep</em></td>
</tr>
<tr>
<td>Antonym</td>
<td>Opposites</td>
<td><em>increase</em> ↔ <em>decrease</em></td>
</tr>
</tbody>
</table>
WordNet Hierarchies: “Vancouver”

WordNet: example from ver1.7.1

For the three senses of “Vancouver”

(city, metropolis, urban center) →
  (municipality) →
  (urban area) →
  (geographical area) →
  (region) →
  (location) →
  (entity, physical thing)

(administrative district, territorial division) →
  (district, territory) →
  (region) →
  (location) →
  (entity, physical thing)

(port) →
  (geographic point) →
  (point) →
  (location) →
  (entity, physical thing)
WordNet Search - 3.1
- WordNet home page - Glossary - Help

Word to search for: bass  Search WordNet

Display Options: (Select option to change)  Change

Key: "S:" = Show Synset (semantic) relations, "W:" = Show Word (lexical) relations
Display options for sense: (gloss) "an example sentence"

Noun

- S: (n) bass (the lowest part of the musical range)
- S: (n) bass, bass part (the lowest part in polyphonic music)
- S: (n) bass, basso (an adult male singer with the lowest voice)
  - direct hypernym / inherited hypernym / sister term
    - S: (n) singer, vocalist, vocalizer, vocaliser (a person who sings)
- S: (n) sea bass, bass (the lean flesh of a saltwater fish of the family Serranidae)
- S: (n) freshwater bass, bass (any of various North American freshwater fish with lean flesh (especially of the genus Micropterus))
- S: (n) bass, bass voice, basso (the lowest adult male singing voice)
- S: (n) bass (the member with the lowest range of a family of musical instruments)
- S: (n) bass (nontechnical name for any of numerous edible marine and freshwater spiny-finned fishes)

Adjective

- S: (adj) bass, deep (having or denoting a low vocal or instrumental range) "a deep voice"; "a bass voice is lower than a baritone voice"; "a bass clarinet"
Wordnet: NLP Tasks

- First success in “obscure” task for Probabilistic Parsing (PP-attachments): words + word-classes extracted from the hypernym hierarchy increase accuracy from 84% to 88% [Stetina and Nagao, 1997]
- Word sense disambiguation
- Lexical Chains (summarization)
- …… and many others!

More importantly starting point for larger Ontologies!
More ideas from NLP….

Relations among words and their meanings
\((\text{paradigmatic})\)

Internal structure of individual words
\((\text{syntagmatic})\)
Predicate-Argument Structure

- Represent relationships among concepts, events and their participants

“I ate a turkey sandwich for lunch”
\[ \exists w: \text{Isa}(w, \text{Eating}) \land \text{Eater}(w, \text{Speaker}) \land \text{Eaten}(w, \text{TurkeySandwich}) \land \text{MealEaten}(w, \text{Lunch}) \]

“Nam does not serve meat”
\[ \exists w: \text{Isa}(w, \text{Serving}) \land \text{Server}(w, \text{Nam}) \land \neg \text{Served}(w, \text{Meat}) \]
Semantic Roles: Resources

• Move beyond inferences about single verbs

  "IBM hired John as a CEO"
  "John is the new IBM hire"
  "IBM signed John for 2M$"

• FrameNet: Databases containing frames and their syntactic and semantic argument structures

• (book online Version 1.5-update Sept, 2010)
  - for English (versions for other languages are under development)

• FrameNet Tutorial at NAACL/HLT 2015!
Hiring

- **Definition:** An *Employer* hires an *Employee*, promising the *Employee* a certain *Compensation* in exchange for the performance of a job. The job may be described either in terms of a *Task* or a *Position* in a *Field*.

- **Inherits From:** Intentionally affect

- **Lexical Units:** commission.n, commission.v, give job.v, hire.n, hire.v, retain.v, sign.v, take on.v
FrameNet: Semantic Role Labeling

Some roles:

<table>
<thead>
<tr>
<th>Employer</th>
<th>Employee</th>
<th>Task</th>
<th>Position</th>
</tr>
</thead>
</table>

- **np-vpto**
  - In 1979, singer Nancy Wilson HIRED him to open her nightclub act.
  - ....

- **np-ppas**
  - Castro has swallowed his doubts and HIRED Valenzuela as a cook in his small restaurant.
Lecture Overview

- **Ontologies** – what objects/individuals should we represent? what relations (unary, binary,..)?
- Inspiration from **Natural Language**: WordNet and FrameNet
- Extensions based on Wikipedia and mining the Web (YAGO, ProBase, Freebase)
- Domain Specific Ontologies (e.g., Medicine: MeSH, UMLS)
YAGO2: huge semantic knowledge base

Derived from Wikipedia, WordNet and GeoNames. (started in 2007, paper in www conference)

10^6 entities (persons, organizations, cities, etc.)

>120* 10^6 facts about these entities.

- YAGO accuracy of 95%. has been manually evaluated.
- Anchored in *time* and *space*. YAGO attaches a *temporal* dimension and a *spatial* dimension to many of its facts and entities.
Freebase

- “Collaboratively constructed database.”

- Freebase contains tens of millions of topics, thousands of types, and tens of thousands of properties and over a billion of facts.

- Automatically extracted from a number of resources including Wikipedia, MusicBrainz, and NNDB

- as well as the knowledge contributed by the human volunteers.

- Each Freebase entity is assigned a set of human-readable unique keys, which are assembled of a value and a namespace.

- All available for free through the APIs or to download from our weekly data dumps.
Probase (MS Research)

- Harnessed from billions of web pages and years worth of search logs
- Extremely large concept/category space (2.7 million categories).
- Probabilistic model for correctness, typicality (e.g., between concept and instance)
Infrastructure

- Web Pages
  - Hearst's Patterns
    - Extract Concepts
    - Extract Entities
  - Split Sentences
  - (Painters, Picasso)
  - (Paintings, Guernica)
  - (Presidents, Bush)
  - (Presidents, Obama)

- Wikipedia
- Freebase
- Wordnet

- Web Table Understanding
- Integration
- Scoring

External Sources Knowledge
A snippet of Probase's core taxonomy

- Markets
  - European Markets
  - Emerging Markets
  - Developing countries
    - Newly Industrialized Countries
      - China
        - Area: 9,596,961 sq km
        - Population: 1.3 billion
        - GDP: $8.7 trillion
      - India
        - Area: 3,287,263 sq km
        - Population: 1.1 billion
        - GDP: $3.57 trillion

Concept
Attribute
Value
Relationship/Similarity
Instance
The Y axis is the number of instances each concept, and on the X axis are the 2.7 million concepts ordered by their size contains (logarithmic scale), and on the X axis are the 2.7 million concepts ordered by their size.
Interesting dimensions to compare Ontologies (but form Probase so possibly biased)

- Covers every topic?
- Knows about everything in a topic?
- Contains rich connections?

Breadth and density enable understanding.
Lecture Overview

• **Ontologies** – what objects/individuals should we represent? what relations (unary, binary,..)?
• Inspiration from **Natural Language**: WordNet and FrameNet
• Extensions based on Wikipedia and mining the Web (YAGO, ProBase, Freebase)
• **Domain Specific Ontologies** (e.g., Medicine: MeSH, UMLS)
Unified Medical Language System: brings together many health and biomedical vocabularies

- Enable interoperability (linking medical terms, drug names)
- Develop electronic health records, classification tools
- Search engines, data mining
Portion of the UMLS Semantic Net
Learning Goals for today’s class

You can:

• Define an Ontology
• Describe and Justify the information represented in Wordnet and Framenet
• Describe and Justify the three dimensions for comparing ontologies
Assignment-3 out - due Nov 20
(10-20 hours - working in pairs on programming parts is strongly advised)
Assignment-2 has been returned

Next class Fri

• Similarity measures in ontologies (Wordnet)

Following class: Mon
Paper discussion
DBpedia is a structured twin of Wikipedia. Currently it describes more than 3.4 million entities. DBpedia resources bear the names of the Wikipedia pages, from which they have been extracted.

YAGO is an automatically created ontology, with taxonomy structure derived from WordNet, and knowledge about individuals extracted from Wikipedia. Therefore, the identifiers of resources describing individuals in YAGO are named as the corresponding Wikipedia pages. YAGO contains knowledge about more than 2 million entities and 20 million facts about them.

Freebase is a collaboratively constructed database. It contains knowledge automatically extracted from a number of resources including Wikipedia, MusicBrainz, and NNDB as well as the knowledge contributed by the human volunteers. Freebase describes more than 12 million interconnected entities. Each Freebase entity is assigned a set of human-readable unique keys, which are assembled of a value and a namespace. One of the namespaces is the Wikipedia namespace, in which a value is the name of the Wikipedia page describing an entity.
Summary

• Relations among words and their meanings
  - Wordnet
  - YAGO
  - Probase

• Internal structure of individual words
  - PropBank
  - VerbNet
  - FrameNet
Table 1: Scale of concept dimension

<table>
<thead>
<tr>
<th>Name</th>
<th># of concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>SenticNet</td>
<td>14,244</td>
</tr>
<tr>
<td>Freebase</td>
<td>1,450</td>
</tr>
<tr>
<td>WordNet</td>
<td>25,229</td>
</tr>
<tr>
<td>WikiTaxonomy</td>
<td>&lt; 127,325</td>
</tr>
<tr>
<td>YAGO</td>
<td>149,162</td>
</tr>
<tr>
<td>DBPedia</td>
<td>259</td>
</tr>
<tr>
<td>ResearchCyc</td>
<td>≈ 120,000</td>
</tr>
<tr>
<td>KnowItAll</td>
<td>N/A</td>
</tr>
<tr>
<td>TextRunner</td>
<td>N/A</td>
</tr>
<tr>
<td>OMCS</td>
<td>23,365</td>
</tr>
<tr>
<td>NELL</td>
<td>123</td>
</tr>
<tr>
<td>Probase</td>
<td>2,653,872</td>
</tr>
</tbody>
</table>
Meaning of words

- Relations among words and their meanings (Paradigmatic)
- Internal structure of individual words (Syntagmatic)
Practical Goal for (Syntax-driven) Semantic Analysis

Map NL queries into FOPC so that answers can be effectively computed

- **What African countries are not on the Mediterranean Sea?**
  \[ \exists c \text{ Country}(c) \land \neg \text{Borders}(c, \text{Med.Sea}) \land \text{In}(c, \text{Africa}) \]

- **Was 2007 the first El Nino year after 2001?**
  \[ \text{ElNino}(2007) \land \neg \exists y \text{ Year}(y) \land \text{After}(y, 2001) \land \text{Before}(y, 2007) \land \text{ElNino}(y) \]
Semantic Analysis

Meanings of grammatical structures

Meanings of words

Common-Sense Domain knowledge

Discourse Structure

Context

Sentence

Syntax-driven

Semantic Analysis

Literal Meaning

Further Analysis

Intended meaning

I am going to SFU on Tue.

The garbage truck just left.

Shall we meet on Tue?

What time is it?
Compositional Analysis

• **Principle of Compositionality**
  - The meaning of a whole is derived from the meanings of the parts

• **What parts?**
  - The constituents of the syntactic parse of the input
Compositional Analysis: Example

- *AyCaramba serves meat*

\[ \exists e \text{ Serving}(e) \land \text{Server}(e, \text{AyCaramba}) \land \text{Served}(e, \text{Meat}) \]
Augmented Rules

- Augment each syntactic CFG rule with a semantic formation rule

- Abstractly

  \[ A \rightarrow \alpha_1...\alpha_n \quad \{ f(\alpha_1.sem,...\alpha_n.sem) \} \]

- i.e., The semantics of A can be computed from some function applied to the semantics of its parts.

- The class of actions performed by \( f \) will be quite restricted.
Simple Extension of FOL: Lambda Forms

- A FOL sentence with variables in it that are to be bound.

- Lambda-reduction: variables are bound by treating the lambda form as a function with formal arguments.

\[ \lambda x P(x) \]

\[ \lambda x P(x)(Sally) \]

\[ P(Sally) \]

\[ \lambda x \lambda y In(x, y) \wedge Country(y) \]

\[ \lambda y In(BC, y) \wedge Country(y) \]

\[ \lambda y In(BC, y) \wedge Country(y)(BC) \]

\[ \lambda y In(BC, y) \wedge Country(y)(CANADA) \]

\[ In(BC, CANADA) \wedge Country(CANADA) \]
Augmented Rules: Example

- **Concrete entities**
  - PropNoun $\rightarrow$ AyCaramba
  - MassNoun $\rightarrow$ meat

- **Simple non-terminals**
  - NP $\rightarrow$ PropNoun
  - NP $\rightarrow$ MassNoun

**Assigning FOL constants**

- **Attachments**
  - {AyCaramba}
  - {MEAT}

**Copying from daughters up to mothers.**

- **Attachments**
  - {PropNoun.sem}
  - {MassNoun.sem}
Augmented Rules: Example

Semantics attached to one daughter is applied to semantics of the other daughter(s).

- $S \rightarrow NP \ VP$  \hspace{1cm} \{\text{VP.sem(NP.sem)}\}
- $VP \rightarrow \text{Verb} \ NP$  \hspace{1cm} \{\text{Verb.sem(NP.sem)}\}

**lambda-form**

- $\text{Verb} \rightarrow \text{serves}$  \hspace{1cm} $\lambda x \lambda y \exists e \ \text{Serving}(e) \land \text{Server}(e, y) \land \text{Served}(e, x)$
Example

\[ S \vdash e \text{ Isa}(e, \text{Serving}) \land \text{Server}(e, AC) \land \text{Served}(e, \text{Meat}) \]

- \( S \rightarrow \text{NP VP} \)
- \( \text{VP} \rightarrow \text{Verb NP} \)
- \( \text{Verb} \rightarrow \text{serves} \)
- \( \text{NP} \rightarrow \text{PropNoun} \)
- \( \text{NP} \rightarrow \text{MassNoun} \)
- \( \text{PropNoun} \rightarrow \text{AyCaramba} \)
- \( \text{MassNoun} \rightarrow \text{meat} \)

- \( \{\text{VP.sem(NP.sem)}\} \)
- \( \{\text{Verb.sem(NP.sem)}\} \)
- \( \lambda x \lambda y \exists e \text{ Serving}(e) \land \text{Server}(e, y) \land \text{Served}(e, x) \)
- \( \{\text{PropNoun.sem}\} \)
- \( \{\text{MassNoun.sem}\} \)
- \( \{\text{AC}\} \)
- \( \{\text{MEAT}\} \)
References (Project?)

• Text Book: Representation and Inference for Natural Language: A First Course in Computational Semantics *Patrick Blackburn and Johan Bos*, 2005, CSLI


Next Time

• Read Chp. 19 (Lexical Semantics)
Next Time

Read Chp. 20

Computational Lexical Semantics

- Word Sense Disambiguation
- Word Similarity
- Semantic Role Labeling
Lexeme:
- **Orthographic form** +
- **Phonological form** +
- **Meaning (sense)**

*[Modulo inflectional morphology]*

- **Lexicon**: A collection of lexemes
Homonymy

Def. Lexemes that have the same “forms” but unrelated meanings

- **Examples:** Bat (wooden stick-like thing) vs. Bat (flying scary mammal thing)
  
  Plant (……..) vs.
  
  Plant (……..)

Homographs

content/content

Homonyms

Homophones

wood/would
Relevance to NLP Tasks

Information retrieval (homonymy):

✓ QUERY: bat

Spelling correction: homophones can lead to real-word spelling errors

Text-to-Speech: homographs (which are not homophones)
Polysemy

Lexeme (new def.):
- Orthographic form + Phonological form +
- Set of related senses

How many distinct (but related) senses?
- They *serve* meat...
- He *served* as Dept. Head...
- She *served* her time....

Different subcat

Intuition (prison)

- Does AC *serve* vegetarian food?
- Does AC *serve* Rome?
- (?)Does AC *serve* vegetarian food and Rome?

Zeugma
Thematic Roles: Usage

Syntax-driven Semantic Analysis

Sentence

Literal Meaning expressed with thematic roles

Further Analysis

Intended meaning

Constraint Generation

Eg. Instrument “with”

Eg. Subject?

Support “more abstract” INFERENCEN

Eg. Result did not exist before
Semantic Roles

- Def. Semantic generalizations over the specific roles that occur with specific verbs.

- I.e. eaters, servers, takers, givers, makers, doers, killers, all have something in common

- We can generalize (or try to) across other roles as well
## Thematic Role Examples

<table>
<thead>
<tr>
<th>Thematic Role</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGENT</td>
<td><em>The waiter</em> spilled the soup.</td>
</tr>
<tr>
<td>EXPERIENCER</td>
<td><em>John</em> has a headache.</td>
</tr>
<tr>
<td>FORCE</td>
<td><em>The wind</em> blows debris from the mall into our yards.</td>
</tr>
<tr>
<td>THEME</td>
<td>Only after Benjamin Franklin broke <em>the ice</em>...</td>
</tr>
<tr>
<td>RESULT</td>
<td>The French government has built a <em>regulation-size baseball diamond</em>...</td>
</tr>
<tr>
<td>CONTENT</td>
<td>Mona asked <em>&quot;You met Mary Ann at a supermarket&quot;</em>?</td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>He turned to poaching <em>catfish</em>, stunning them with a shocking device...</td>
</tr>
<tr>
<td>BENEFICIARY</td>
<td>Whenever Ann Callahan makes hotel reservations <em>for her boss</em>...</td>
</tr>
<tr>
<td>SOURCE</td>
<td>I <em>flew in</em> from Boston.</td>
</tr>
<tr>
<td>GOAL</td>
<td>I drove <em>to Portland</em>.</td>
</tr>
</tbody>
</table>
# Thematic Roles

<table>
<thead>
<tr>
<th>Thematic Role</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGENT</td>
<td>The volitional causer of an event</td>
</tr>
<tr>
<td>EXPERIENCER</td>
<td>The experiencer of an event</td>
</tr>
<tr>
<td>FORCE</td>
<td>The non-volitional causer of the event</td>
</tr>
<tr>
<td>THEME</td>
<td>The participant most directly affected by an event</td>
</tr>
<tr>
<td>RESULT</td>
<td>The end product of an event</td>
</tr>
<tr>
<td>CONTENT</td>
<td>The proposition or content of a propositional event</td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>An instrument used in an event</td>
</tr>
<tr>
<td>BENEFICIARY</td>
<td>The beneficiary of an event</td>
</tr>
<tr>
<td>SOURCE</td>
<td>The origin of the object of a transfer event</td>
</tr>
<tr>
<td>GOAL</td>
<td>The destination of an object of a transfer event</td>
</tr>
</tbody>
</table>

- Not definitive, not from a single theory!
Problem with Thematic Roles

- NO agreement of what should be the standard set
- NO agreement on formal definition
- **Fragmentation problem:** when you try to formally define a role you end up creating more specific sub-roles

Two solutions

- Generalized semantic roles
- Define verb (or class of verbs) specific semantic roles
Generalized Semantic Roles

- **Very abstract roles are defined heuristically as a set of conditions**
- **The more conditions are satisfied the more likely an argument fulfills that role**

**Proto-Agent**
- Volitional involvement in event or state
- Sentience (and/or perception)
- Causing an event or change of state in another participant
- Movement (relative to position of another participant)
- (exists independently of event named)

**Proto-Patient**
- Undergoes change of state
- Incremental theme
- Causally affected by another participant
- Stationary relative to movement of another participant
- (does not exist independently of the event, or at all)
Semantic Roles: Resources

- Databases containing for each verb its syntactic and thematic argument structures
  - PropBank: sentences in the Penn Treebank annotated with semantic roles
  - Roles are verb-sense specific
  - Arg0 (PROTO-AGENT), Arg1(PROTO-PATIENT), Arg2, .......

  • (see also VerbNet)
PropBank Example

• **Increase** “go up incrementally”
  - Arg0: causer of increase
  - Arg1: thing increasing
    - Arg2: amount increase by
      - Arg3: start point
      - Arg4: end point

• PropBank semantic role labeling would identify common aspects among these three examples
  - "Y performance increased by 3%"
  - "Y performance was increased by the new X technique"
  - "The new X technique increased performance of Y"

Glosses for human reader. Not formally defined