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# *CSCE 771:* Computer Processing of Natural Language
## Lecture 9: Semantics

PROF. BIPLAV SRIVASTAVA, AI INSTITUTE

15TH SEPTEMBER, 2022

***Carolinian Creed: "I will practice personal and academic integrity."***

Acknowledgement: Used materials by Jurafsky & Martin, 2nd edition

# Organization of Lecture 9

- Opening Segment
  - Announcement
- Main Lecture

Main Section
- Semantics
  - Shallow: similarity, relatedness; frames
  - Propbank
  - Deep: AMR
  - ConceptNet
- Review projects

- Concluding Segment
  - Reading material:
  - About Next Lecture – Lecture 10

| | | |
|---|---|---|
| 7 | Sep 8 (Th) | Statistical Parsing, QUIZ |
| 8 | Sep 13 (Tu) | Review Parsing, Quiz review, Review Project, Introduce Evaluation |
| 9 | Sep 15 (Th) | Semantics |
| 10 | Sep 20 (Tu) | Review: Machine Learning for NLP, Evaluation – Metrics |
| 11 | Sep 22 (Th) | Language Model – Vector embeddings, CNN/ RNN |
| 12 | Sep 27 (Tu) | Guest Lecture – Dr. Amitava Das: Glove, Word2Vec, Transformer Review: Reasoning for NLP |
| 13 | Sep 29 (Th) | Representation: Ontology, Knowledge Graph, QUIZ |
| 14 | Oct 4 (Tu) | Representation: Embeddings, Language Models |
| 15 | Oct 6 (Th) | Entity extraction |
| 16 | Oct 11 (Tu) | Guest Lecture – Dr. Amitava Das: Using lang models to solve NLP tasks |

# Announcements

GUEST LECTURES ON LANGUAGE MODELS BY DR. AMITAVA DAS

## Upcoming In-person talk

2:20 pm - 3:10 pm, at the **Seminar in Advances in Computing**, Dr. Biplav Srivastava from UofSC will give an in-person talk entitled “Can we ever trust our chatbots? Towards trustable collaborative assistants”.

**In-Person Meeting Location:**
Storey Innovation Center 1400

**Abstract:**
AI services are known to have unstable behavior when subjected to changes in data, models or users. Such behaviors, whether triggered by omission or commission, lead to trust issues when AI work with humans. The current approach of assessing AI services in a black box setting, where the consumer does not have access to the AI’s source code or training data, is limited. The consumer has to rely on the AI developer’s documentation and trust that the system has been build as stated. Further, if the AI consumer reuses the service to build other services which they sell to their customers, the consumer is at the risk of the service providers (both data and model providers).

In this talk, I will cover chatbots (collaborative assistants), the problem of trust in this context and how one may make them more trustable. We will cover software testing, AI robustness, randomized control trial and the idea of rating AI based on their behavior. I will highlight some of our work, present key results and discuss ongoing work.

## Upcoming virtual talk

# NLP AND SOCIETY

## A PERSPECTIVE FROM SENTIMENT AND EMOTION ANALYSIS, AND MENTAL HEALTH MONITORING

MONDAY
**SEPTEMBER**
**19**
10 a.m.
Online on **Zoom**
**Meeting ID:** 860 1921 3021
**Passcode:** 12345

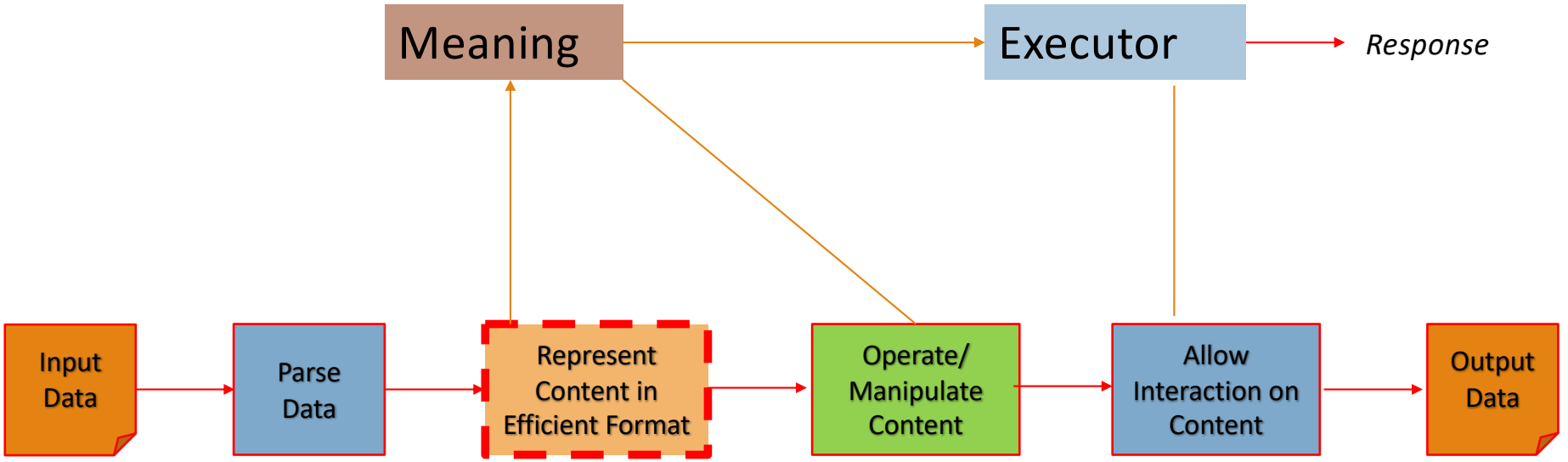
**PROF. PUSHPAK BHATTACHARYA**
INDIAN INSTITUTE OF TECHNOLOGY (IIT) BOMBAY

**Bio:** Dr. Pushpak Bhattacharyya is a Professor of Computer Science and Engineering at IIT Bombay. He has done extensive research in Natural Language Processing and Machine Learning. Some of his noteworthy contributions are IndoWordnet, Eye Tracking assisted NLP, Low Resource MT, Multimodal multitasked multilingual sentiment and emotion analysis, and Knowledge Graph-Deep Learning Synergy in Information Extraction and Question Answering. He has published close to 400 research papers, has authored/co-authored 6 books including a textbook on machine translation, and has guided more than 350 students for their Ph.D., master's, and Undergraduate thesis. Prof. Bhattacharyya is a Fellow of the National Academy of Engineering, Abdul Kalam National Fellow, Distinguished Alumnus of IIT Kharagpur, past Director of IIT Patna, and past President of ACL.
**http://www.cse.iitb.ac.in/~pb**

**Abstract:** In this talk, we describe our long-standing work on sentiment and emotion analysis, and also the use of NLP for mental health monitoring. The last mentioned is a stigma that society prefers to keep under cover, but with hazardous consequences. We describe our contribution to the techniques of sentiment and emotion analysis- often multimodal, multitasking, and multilingual. Such techniques have also proven useful in monitoring mental distress and providing positivity and hope through NLP agents. The work reported is the result of efforts of generations of students, and has found a place in top journals and conferences.

# Main Lecture

# Semantics, Parsing and Representation



# Semantics

- ***lexical semantics****:* studies word meanings and word relations, and
- ***formal semantics****:* studies the logical aspects of meaning, such as sense, reference, implication, and logical form
- ***conceptual semantics****:* studies the cognitive structure of meaning

Source: Jurafsky & Martin, Wikipedia (https://en.wikipedia.org/wiki/Semantics)

# From Text to Meaning

- Shallow semantics
  - Input: text
  - Output: ***lexical semantics***
- Deep semantics
  - Input: text
  - Output: ***formal semantics***

**LOGIC format**:

$\exists$ w, b, g:
instance(w, want-01) $\wedge$ instance(g, go-01) $\wedge$
instance(b, boy) $\wedge$ arg0(w, b) $\wedge$
arg1(w, g) $\wedge$ arg0(g, b)

**AMR format** (based on PENMAN):

```
(w / want-01
  :arg0 (b / boy)
  :arg1 (g / go-01
          :arg0 b))
```

**GRAPH format**:

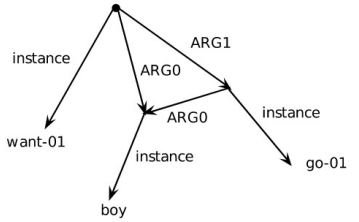



Figure 1: Equivalent formats for representating the meaning of "The boy wants to go".

Source: Abstract Meaning Representation for Sembanking, https://amr.isi.edu/a.pdf

# Review: Common Definitions

- **Corpus** (plural corpora): a computer-readable corpora collection of text or speech.
- **Lemma**: A lemma is a set of lexical forms having the same stem, the same major part-of-speech, and the same word sense. Example: Cat and cats have same lemma.
- **Word form**: The word form is the full inflected or derived form of the word. Example: Cat and cats have different word forms.
- **Word type**: Types are the number of distinct words in a corpus. if the set of words is V, the number of types is the word token vocabulary size |V|.
- **Word tokens**: The total number N of running words in the sentence / document of interest.
- **Code switching**: use multiple languages in a code switching single communicative act – Example: Hindlish (Hindi English), Spanish (Spanish English)

"They picnicked by the pool, then lay back on the grass and looked at the stars."

- 16 tokens, 14 word types

Source: Jurafsky & Martin

# Lexical Semantics

- Lemma
  - Sing, Mouse
- Word form
  - Sing, sang, sung
  - Mouse, mice
- Word sense
  - Mouse: a rodent
  - Mouse: an electronic pointing device

A lemma having many senses is called **Polysemous**

# Synonymous and Similar Words

- **Synonym** - one word has a sense whose meaning is identical to a sense of another word
  - Two words are **synonymous** if they are substitutable one for the other in any sentence without changing the truth conditions of the sentence, the situations in which the sentence would be true
  - **Propositional meaning** – synonym words have the same propositional meaning (truth preserving)
- **Principle of contrast** – An assumption in linguistics is that difference in linguistic form (e.g., word form) is always associated with at least some difference in meaning
  - Water and H20 are truth preserving but used in different context
  - Synonym words are used for approximate synonymy. Then, how similar are the words?

Source: Jurafsky & Martin

# Word Similarity - SimLex-999

- Captures similarity between word pairs, mining the opinions of 500 annotators via Amazon Mechanical Turk on a scale of 1 to 10

**Note***: similarity,* rather than *relatedness* or *association*

- Contains
  - 666 Noun-Noun pairs,
  - 222 Verb-Verb pairs
  - 111 Adjective-Adjective pairs

| | | |
|---|---|---|
| vanish | disappear | 9.8 |
| behave | obey | 7.3 |
| belief | impression | 5.95 |
| muscle | bone | 3.65 |
| modest | flexible | 0.98 |
| hole | agreement | 0.3 |

Source: Jurafsky & Martin

- **Usage**: Evaluation of learning based approaches for finding word similarity by correlation

SimLex-999: Evaluating Semantic Models with (Genuine) Similarity Estimation. 2014. Felix Hill, Roi Reichart and Anna Korhonen. *Computational Linguistics.* 2015
Website: https://fh295.github.io/simlex.html

# Meaning (Semantics) versus Structure (Lexical)

| Pair | Simlex-999 rating | WordSim-353 rating |
|---|---|---|
| *coast - shore* | 9.00 | 9.10 |
| *clothes - closet* | 1.96 | 8.00 |

Example courtesy: https://fh295.github.io/simlex.html

# Word Relatedness/ Association

- **Semantic Field:** related words from the same particular domain and bear structured relations with each other.
  - Example 1: cup, coffee
  - Example 2: scalpel, surgeon
  - Usually determined by experts in a field

Source: Jurafsky & Martin

- **Word Association Test/ Task:** how word meaning is stored in memory
  - Have people respond to word associations as a game; e.g., say the first word that comes to mind when one says "Doctor"
  - Applications
    - Used in marketing
    - Also evaluation of learning procedures discovering meaning (e.g., word embedding)

**Sources**:
- https://psychology.jrank.org/pages/656/Word-Association-Test.html,
- Establishing the Reliability of Word Association Data for Investigating Individual and Group Differences , Tess Fitzpatrick, David Playfoot, Alison Wray, Margaret J. Wright *Applied Linguistics*, Volume 36, Issue 1, February 2015, Pages 23–50, https://doi.org/10.1093/applin/amt020

# Discovering Word Relatedness

- **Topic model**: a statistical notion of related words in a document. Hope is that meaningful topics will be from the same semantic field, but there is no guarantee
- Key idea
  - Topic: group of words
  - Counting words and grouping similar word patterns to infer topics within unstructured data.
  - Assumptions
    - Distributional hypothesis: similar topics make use of similar words
    - Statistical mixture hypothesis: documents talk about several topics
  - Perform unsupervised analysis/ clustering: given a corpus and number of topics (k), find k topics that are representative of key ideas in the corpus

**References**:

- Blog: https://monkeylearn.com/blog/introduction-to-topic-modeling/
- Tool: Gensim
- Paper: https://www.jmlr.org/papers/volume3/blei03a/blei03a.pdf

# Frames, Slots: Frame Semantics

- Examples
  - "John sold a car to Mary”
  - "Mary bought a car from John”
  - “Mary paid John a undisclosed amount to get his car”
- To understand a word, one needs to understand the knowledge related to the word
  - In example: sell, buy, pay
- Capture knowledge in structures called **semantic frames** which have placeholders called slots (variables)
  - During parsing of sentences, values are filled
- **Frame semantics** is a theory of linguistic meaning developed by Charles J. Fillmore; related notion is semantic parsing

# PropBank FrameSet

- A repository of formalized predicates
  https://propbank.github.io/

```
<roleset id="care.01”
        name="having an opinion, feeling tenderly/strongly
for/about">
<roleset id="care.02"
        name="liking/desiring/wanting">
<roleset id="care.03"
        name="tending, taking care of">
<roleset id="care.04"
        name="being cautious, taking care to">
```

Example: Care
https://github.com/propbank/propbank-frames/blob/main/frames/care.xml

Hindi – भेजा - ***Beja***

Credits: https://verbs.colorado.edu/propbank/framesets-hindi/Beja-v.html

# Example: Hindi Propbank

**Roleset id: Beja.01 , *to send, transport, ship something***
- **Arg0**: *the one who sends something*
- **Arg2**: *the recipient to whom something is sent*
- **Arg1**: *the thing that is sent*

**Roleset id: Beja.02 , *to send, transport, ship something***
- **Arg0**: *the one who sends something*
- **Arg2-gol**: *the place where something is sent*
- **Arg1**: *the thing that is sent*

**Roleset id: Beja.03 , *to make someone send something to someone***
- **Argc**: *the causer- the one who makes someone send something*
- **Arga**: *the intermediate causer*
- **Arg0**: *the agent- the one who sends something*
- **Arg2**: *the one to whom something is sent*
- **Arg1**: *the thing that is sent*

**Roleset id: Beja.04 , *to make someone send something to someplace***
- **Argc**: *the causer- the one who makes someone send something*
- **Arga**: *the intermediate causer*
- **Arg0**: *the agent- the one who sends something*
- **Arg2-gol**: *the place where something is sent*
- **Arg1**: *the thing that is sent*

# Abstract Meaning Representation (AMR)

- Example: “The boy wants to go”
- AMR concepts are
  - English words (“boy”),
  - PropBank framesets (“want-01”), or
  - special key-words.
- Keywords include special entity types(“date-entity”, “world-region”, etc.), quantities(“monetary-quantity”, “distance-quantity”, etc.)
- logical conjunctions (“and”, etc).
- AMR uses approximately 100 relations

Source: Abstract Meaning Representation for Sembanking, https://amr.isi.edu/a.pdf

**LOGIC format**:

∃ w, b, g:
instance(w, want-01) ∧ instance(g, go-01) ∧
instance(b, boy) ∧ arg0(w, b) ∧
arg1(w, g) ∧ arg0(g, b)

**AMR format** (based on PENMAN):

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**GRAPH format**:

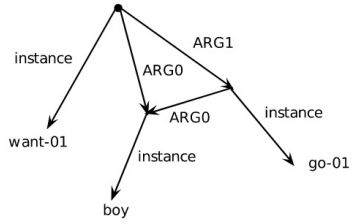
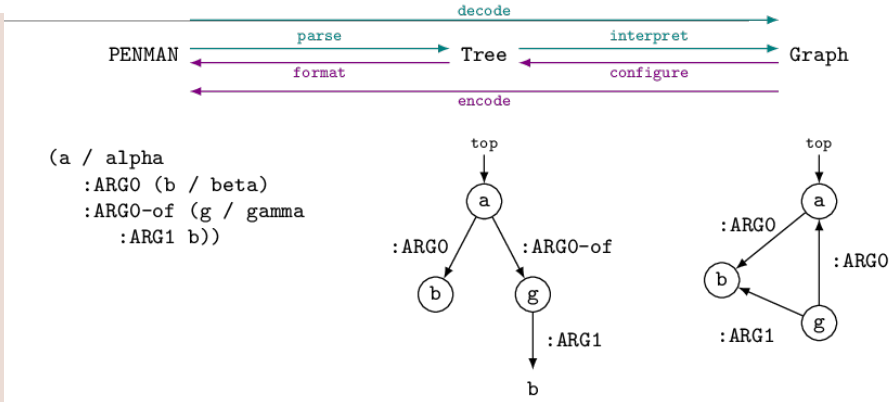



Figure 1: Equivalent formats for representating the meaning of “The boy wants to go”.

# PENMAN Notation

```
;  ┌──────────────────────────── Variable (this one is the graph's top)
;  │   ┌──────────────────────── Instance relation
;  ┴ ____┴_____
   (d / drive-01
;     ┬ ──┬────
;     │   └──────────────────── Concept (node label)
;     └──────────────────────── Indicates the node's concept
;         ┌──────────────────── Edge relation
;     ______┴_______
      :ARG0 (h / he)
;     ──┬──
;       └──────────────────────── Role (edge label)
      :manner (c / care-04
;                 ┌──────── Attribute relation
;             ─────┴─────
              :polarity -))
;                   ┬
;                   └── Atom (or "constant")
```




**Credit**: https://penman.readthedocs.io/en/latest/structures.html

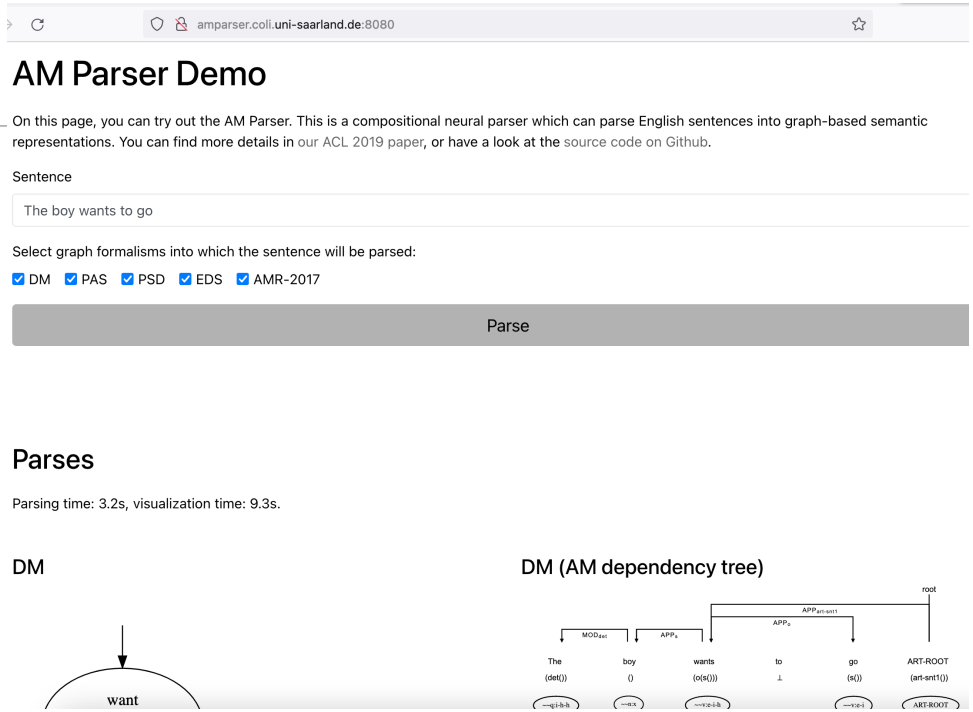
**Credit**: https://penman.readthedocs.io/en/latest/notation.html

# Sample Code – PENMAN/ AMR

**Sample code:**
https://github.com/biplav-s/course-nl-f22/blob/main/sample-code/l9-semantics/PENMAN%20Notation%20-%20AMR.ipynb

# AMR Demo

http://amparser.coli.uni-saarland.de:8080/



# Exercise: 5 mins

- Try your sentences online
- Look at output in different formats

# Semantic Parsing

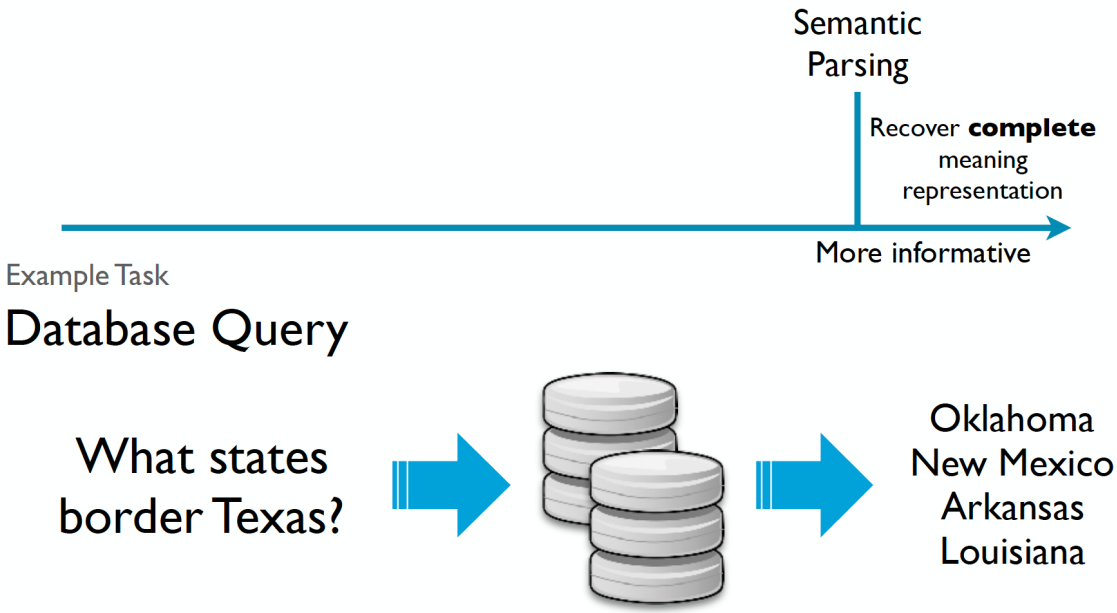
- Shallow semantic parsing
  - Also called: slot-filling or frame semantic parsing
  - "show me flights from Boston to Dallas"
- Deep semantic parsing
  - “show me flights from Boston to anywhere that has flights to Dallas”
  - Reference to quantifiers

Applications
- Paraphrasing
- Machine comprehension
- Question-answering
- Dialog

References:
- ACL 2020 Tutorial on Semantic Parsing
- https://en.wikipedia.org/wiki/Semantic_parsing

# Semantic Parsing

## Language to Meaning




Task-specific parsing

Source:
ACL 2020 Tutorial on Semantic Parsing

# Resources: Semantic Parsing Libraries

- Open Sesame
  - Given English sentence, predicts FrameNet frames
  - https://github.com/swabhs/open-sesame

- AMRLib
  - Python library for AMR parsing, generation and visualization simple
  - https://github.com/bjascob/amrlib

# Review: Lexical Meaning – Common Terms

- **Synonym**: same/ similar meaning
  - start-begin, finish-end, far-distant
- **Antonym**: opposite meaning
  - Far – near, clever - stupid, high - low, big – small
- **Homonym**: identical in spelling and pronunciation
  - bear, bank, ...
- **Homophones**: sounds identical but are written differently
  - site-sight, piece-peace.
- **Homograph**: written identically but sound differently
  - Potato, tomato, lead, wind, minute
- **Polysemy**: a word or phrase which has two (or more) different meanings (i.e., senses)
  - Duck, sharp

Source: Mausam

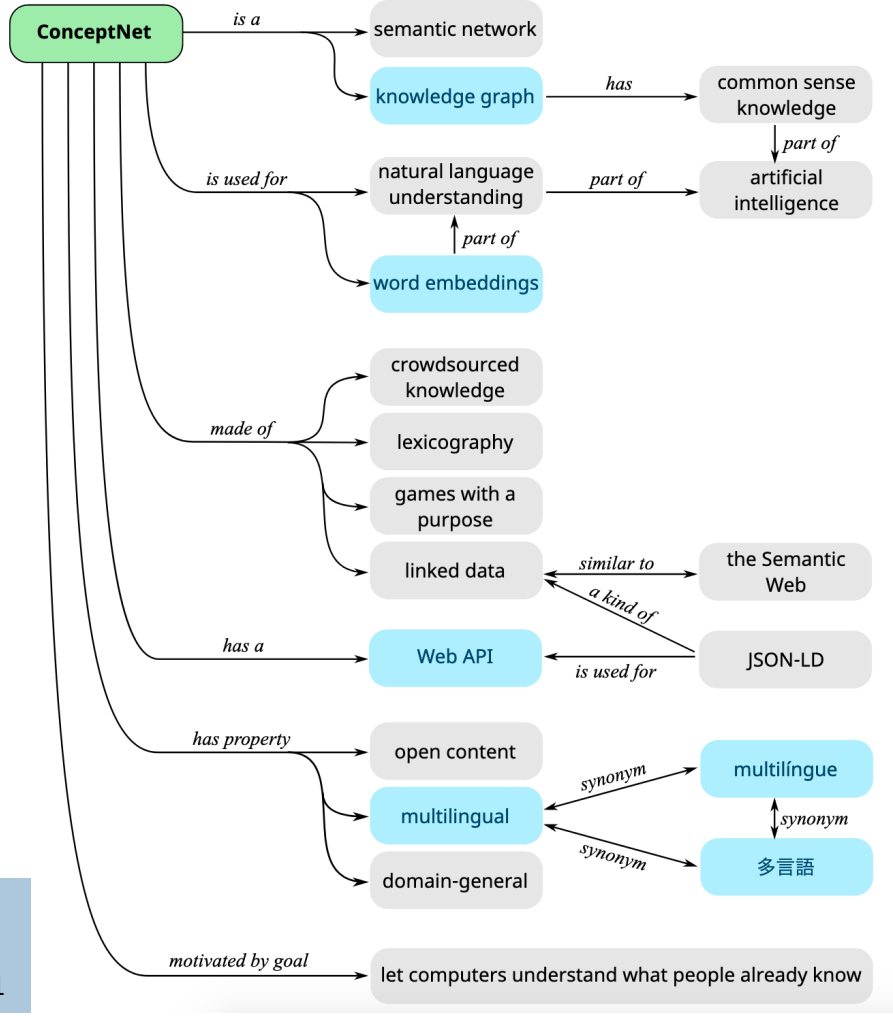
# More Terms

- **Affective meanings** or **connotation**: word's meaning that are related to a writer or reader's emotions, sentiment, opinions, or evaluations
  - Positive evaluation: good, happy
  - Negative evaluation:
- **Sentiment**: Positive or negative evaluation expressed through language
  - Scherer's Typology of Affective States

Source: Jurafsky & Martin

# ConceptNet

- NLP focused graph knowledge graph that connects words and phrases of natural language with labeled edges.
- Concepts collected from experts, crowd-sourcing, and games with a purpose
- Supports multiple languages
- Provides ”loose” semantics - relatedness




**Details:** http://conceptnet.io/, https://github.com/commonsense/conceptnet5/wiki,
**Paper**: https://www.aaai.org/ocs/index.php/AAAI/AAAI17/paper/viewFile/14972/14051

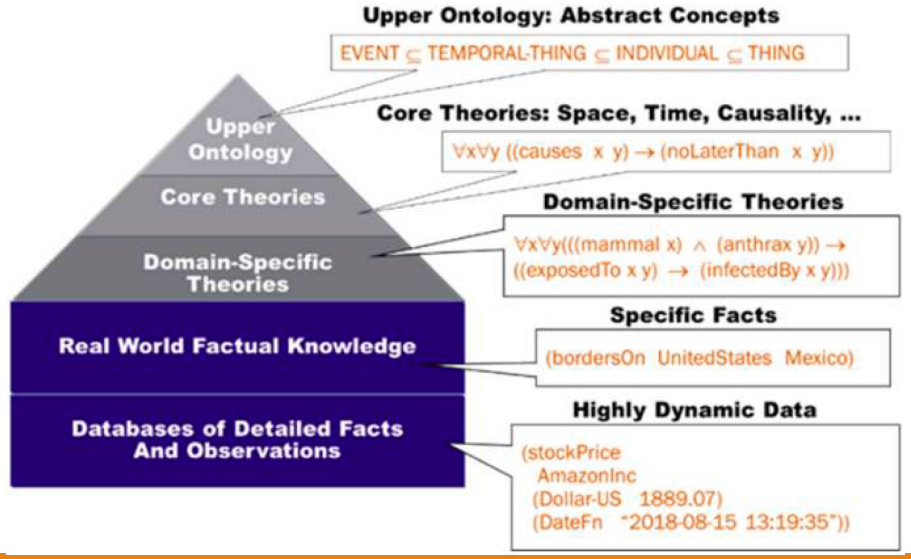
# Demonstration - ConceptNet

**Examples**:

- Concepts:
  - Word: http://conceptnet.io/c/en/word ,
  - duck: http://conceptnet.io/c/en/duck
- Relationships:
  - http://conceptnet.io/s/resource/wordnet/rdf/3.1

# Project CYC

- A large ontology to capture the world and human common sense
  - Doug Lenat lead team of computer scientists, computational linguists, philosophers, and logicians
  - Identify and formally axiomatize the tens of millions of rules about world
  - 35+ years effort by Cycorp
- Reasoners on the ontology to make decisions
  - 1000+ specialized reasoners




**Details:** https://www.cyc.com/

**Source**: Cyc White Paper

# Cyc Details

- Ontology of about 1.5 million general concepts (e.g., taxonomically "placing" terms like eyes, sleep, night, person, unhappiness, hours, posture, being woken up, etc.);
- More than 25 million general rules and assertions involving those concepts
  - *"Most people sleep at night, for several hours at a time, lying down, with their eyes closed, they can be awakened by a loud noise but don't like that, "*
- Domain-specific extensions to the common sense ontology and knowledge base
  - healthcare, intelligence, defense, energy, transportation and financial services.
- Promoting synergistic use of ontology and learning based approaches (now)

Source: White Paper – Cyc Technology Overview

# Lecture 9: Concluding Comments

- We reviewed how to give semantics to words and documents
- Can be human supervised or learning based or combined
- Can be generic or task-oriented

# Concluding Segment

# About Next Lecture – Lecture 10

# Lecture 10 Outline

- Machine Learning for NLP
  - Supervised learning
  - Unsupervised learning
  - Neural methods