# 6.863J Natural Language Processing Lecture 15: Word semantics Working with Wordnet 

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## The Menu Bar

- Administrivia:
- Lab 4 due April 9 (Weds.);
- Start w/ final projects, unless there are objections
- Agenda:
- Working with Wordnet
- What's Wordnet
- What can we do with it?
- Solving some reasoning problems:
- Mending a torn dress
- Enjoying a movie; What's a shelf?
- Implementing EVCA and Wordnet together


## Wordnet motivation

But people have persistent problem. When they look up a word, especially a commonly used word, they often find a dozen or more different meanings. What the dictionary does not make clear are the contexts in which each of these different meanings would be understood. So we know what kind of information is required, but we have not yet learned how to provide it to a computer.
(G. Miller, U.S./Japan Joint Workshop on Electronic Dictionaries and Language Technologies January 23--25, 1993.)

## What's Wordnet?

- Psychological motivation
- Nouns, verbs, adjectives organized into (fairly) distinct networks of
- Synonym Sets (synsets)
- Each synset = 1 concept
- Supposedly intersubstitutable within synset ("synonomy")


## Practical motivation

- What's not in a dictionary?
- Take example, like tree - "large, woody perennial plant with a distinct trunk"
- What info is missing?


## Psychological motivation

- Why these categories?
- Words association: first word thought of drawn from difft syntactic categories
- Modal response - same as probe: noun probes elicit nouns 79\% of the time; verbs, v's, 43\%; adjs, adjs 65\%
- Not just contiguity (since that fails)
- "Middle level" descriptions for nouns


## Psychological motivation

- Where do categories come from??
- How do we 'carve up' nature at its joints?


## Synonomy

- Two entries synonyms if the can be substituted in some context
- set of synonyms= Synset
- \{chump, fish, fool, gull, mark, patsy, fall guy, sucker, schlemiel, shlemiel, soft touch, mug\}
- "easy to take advantage of"
- A concept that has been lexicalized


## Basic stats

- POS Unique Strings Synsets Word-Sense Pairs
Noun $109195 \quad 75804134716$
Verb $11088 \quad 13214 \quad 24169$
Adjective $21460 \quad 1857631184$

| Adverb | 4607 | 3629 | 5748 |
| :--- | :--- | :--- | :--- |


| Totals 146350 | 111223 | 195817 |
| :--- | :--- | :--- | :--- |

## Example synset



## U do it


smoke

## Add relations... then stir

- Concepts related through (possibly iterated) applications of basic relation:

1. Is-a relation (Hypernym): from concept to superordinate (denoted $\rightarrow$ )
e.g., breakfast $\rightarrow$ meal

This is unidirectional
2. Meronymy ("part of")
3. Antonymy (opposite)

Note: multiple inheritance;
No unique 'top' concept: dirt has top concept entity; while gossip has act
Is-a merges function/nonfunctional isa relations

## Wordnet relations



## Wordnet Relations

| $X$ hyp $Y$ | $Y$ hypernym of $X$ | $X$-repair, $y$-improve |
| :--- | :--- | :--- |
| $X$ ent $Y$ | $X$ entails $Y$ | $X$-breathe, $Y$-inhale |
| $X$ sim $Y$ | (adj) $Y$ s similar $X$ | $X$-achromatic, $y$-white |
| $X$ cs $Y$ | $Y$ is a cause of $X$ | $X$-anesthetize, $y$-sleep |
| $X$ vgp $Y$ | (verbs) $Y$ similar $X$ | $X$-behave, $y$-pretend |
| $X$ ant $Y$ | $X, Y$ antonyms | $X$-present, $Y$-absent |
| $X$ sa $Y$ | $X$ see also $Y$ | $X$-breathe, $y$-breathe out |
| $X$ ppl $Y$ | $X$ participle of $Y$ | $X$-applied, $y$,apply |
| $X$ per $Y$ | $X$ pertains to $Y$ | $X$-abaxial, $Y$-axial |

## Noun relations

| Relation | Definition | Example |
| :--- | :--- | :--- |
| Hypernym | From concepts to superordinates | breakfast $\rightarrow$ meal |
| Hyponym | From concepts to subtypes | meal $\rightarrow$ lunch |
| Has-Member | From groups to their members | faculty $\rightarrow$ professor |
| Member-Of | From members to their groups | copilot $\rightarrow$ crew |
| Has-Part | From wholes to parts | table $\rightarrow$ leg |
| Part-Of | From parts to wholes | course $\rightarrow$ meal |
| Antonym | Opposites | leader $\rightarrow$ follower |

## Verb relations

| Relation | Definition | Example |
| :--- | :--- | :--- |
| Hypernym | From events to superordinate events | fly $\rightarrow$ travel |
| Troponym | From events to their subtypes | walk $\rightarrow$ stroll |
| Entails | From events to the events they entail | snore $\rightarrow$ sleep <br> Ancrease $\Longleftrightarrow$ decrease |
| Antonym | Opposites | increater |

## Wordnet: why?

- Can draw inferences about some events
- We'll give 3 case studies...
- Consider first:

1. Susan mended the torn dress
2. Susan mended the red dress

- Mend refers to some action, resulting in a change of state for direct objects


## The inferential questions

- For 1: After the dress is mended, is it still torn?
- For 2: After the dress is mended, is it still red?
- Call this 'semantic opposition', e.g.:
- The woman on the boat jumped into the river
- The prisoner escaped from prison


## "event template" idea doesn't help

- [x cause [become [y <mended> ] ] ]


## And more examples

- The plumber fixed every leaky faucet
- The plumber fixed every blue faucet
- Mary fixed the flat tire
- The mother comforted the crying child
- John painted the white house blue
- Mary rescued the drowning man

These are all examples of the famous...

## Frame Problem in AI!

- Which things remain the same in a changing world?
- McCarthy and Hayes "Some Philosophical Problems from the Standpoint of Artificial Intelligence, (1969).(Machine Intelligence 4, 463502)
- "except for things explicitly known to change, everything else remains the same"


## Yet other examples

- Not just change of state verbs:
- John brushed the dirty carpet
- John brushed the dirty carpet clean
- (seep, wipe, broom, paint,...)


## Wordnet solution

- Use transitivity of hypernym relation
- Given adjective \& change of state verb:
- Compute shortest path between them in Wordnet
- If antonym exists on the path, then cancel the adjective
- Otherwise, the adjective still prevails
- A test of transitivity, and Wordnet


## Example

- mend vs. tear
- Repair is in same synset
- Break and bust\#1 are in same synset
- Bust\#1 and Bust\#3 both verbs of contact
- Bust\#3 in same synset as tear
- So chain looks like this:


## This path or bust


Len=5

## Can't get there from here

- 5 other ways (longer chains) between mend and tear (one w/o antonym):

1. Mend and fix in same synset
2. Fix1 and Fix 3 in synsets related by verb change
3. Fix3 is an instance of attach
4. Attach1 and attach3 in synsets related by verb contact
5. Attach 3 instance of touch
6. Touch1 and touch3 in synsets related by verb contact
7. Touch see also touch down
8. Touch down instance of land
9. Land and shoot down in same synset
10. Shoot down1 and shoot down2 in synsets related by verb of motion
11. Shoot down2 and tear in same synset

## OK, how does this work?

- Do BFS on nodes - unidirectional
- Bi-directional would work even better
- 11 test examples 9 work, 2 don't


## Mary rescued...

Parsing: Mary rescued the drowning man
drown/v (200329171,1)
instance of eliminate/v $(200328742,1)$
instance of destroy/v (201114042,1)
instance of unmake/v $(201113462,1)$
and make/v $(201113245,2)$ are antonyms
and make/v (201185771,4) in synsets related by verb.creation instance of direct/v $(201661432,1)$
instance of deal/v (201658906,2)
and deal/v (201619807,1) in synsets related by verb.social instance of deport/v $(201716569,4)$
and deport/v (201706176,3) in synsets related by verb.social and deliver/v (201706176,2) in same synset
and deliver/v $(201739567,2)$ in synsets related by verb.social and rescue/v $(201739567,1)$ in same synset
15 fal.

| Test caseS |  |  |  |
| :--- | :---: | :---: | ---: |
| Pair |  |  |  |
| Chain len | Semantic <br> opposition | Search size |  |
| mend-tear | 5 | Yes | 1261 |
| mend-red | - | No | 11974 |
| fix-leaky | 5 | Yes | 12167 |
| fix-blue | 11 | No | 14553 |
| fix-flat | - | No | 12298 |
| mix-powdered | 6 | Yes | 11931 |
| comfort-crying | 9 | Yes | 11359 |
| blue-white | - | No | 24431 |
| rescue-drowning | 13 | Yes | 9142 |
| clean-dirty | 1 | Yes | 61 |
| fill-empty | 1 | Yes | 48 |

## Why the failures - analysis

- Can we reduce length threshold below 11? No...
- Why does the color system fail?


## Color system in Wordnet

argent blue-black charcoal gray hueless neutral white


## chromatic

amber azure blue brown dun green red ... yellow

1. white and achoomatic $(300367747,2)$ in same synset
2. achomatic $(300364634,1)$ and chomatic $(300355823,1)$ are antonyms
3. chromatic ( 300355823,1 ) and b/we are similar

## Wordnet defects for semantic inference

- Shortest path/threshold only work if length of chain inversely correlated with reliability
- Semantic opposition not always encoded how to do this?


## Application 2: logical metonomy: telic (functional/purposive) roles distinguished <br> - What's that?

(1) a. John began the novel (reading writing)
b. The author began the unfinished novel back in 1962 (writing)

- Begin can have Agent role, for the writer, or it can be a Telic role (function), for the reader
- Problem is how to define 'context' here


## Application 2: Metonomy

- John began the novel (reading/writing)
- Context can alter: He realy enjoyed your book (reading)
- My dog eats anything
- He really enjoyed your book (eating)
- !John enjoyed the rock
- !! John enjoyed the door


## Using Wordnet here

- Wordnet can pick out contexts in which NPs represent events, relative to classes (types)
- Point is: locus of variation is not lexical structure, but in more general ontology (we shall return to this point later)


## 'Enjoy' has lots of purposes...

a. Mary enjoyed seeing the garden
b. Mary enjoyed inspecting the garden
c. Mary enjoyed visifing the garden
d. Mary enjoyed strolling through the garden
c. Mary enjoyed rollerblading in the garden
f. Mary enjoyed sitting in the garden
g. Mary enjoyed dozing in the garden

How can we recover these - distinguish between agent and telic (function) roles?

## Context can be subtle

- He really enjoyed your book (reading)
- My dog eats anything
- He really enjoyed your book (eating)


## 2 contextual function search rules using Wordnet

Principle of Specificity: Prefer $R_{i}$ to $R_{j}$ in the sequence


Principle of Locality: Plausibility of $R_{i}$ scales with $m$ and inversely with $l$ in


## Test verb

a. EXP enjoy NP
b. EXP ${ }_{i}$ enjoy $\left[\mathrm{PRO}_{i}[\mathrm{~V}(\right.$ ing $\left.) \mathrm{NP}]\right]$

## Mary enjoyed the cigarette (smoking)

## Wordnet



## Check

## Mary enjoyed the cigarette (smoking)

Given the hypernym hierarchy in (13), smoke(PRO,cigarette) is the strongly preferred interpretation since the concept smoke is highly specific ( $l$ small) and distant from general concepts artifact and physical object ( $m$ large).

## Links for sonata

a. Mary enjoyed the sonata (listening to/playing)
b. Mary began the sonata (playing/composing)


## For begin

music $\longrightarrow$ art $\longrightarrow$ creation $\longrightarrow$ artifact
compose, $\qquad$ write

## Door...

## !!John enjoyed the door



Specifically, a door can function both as an entrance (enter) and a barrier (block) to an enclosure. However, the telic verb block has form block(door,ENCLOSURE), which is incompatible with the prototype $V(\mathrm{PRO}$, door $)$, thus ruling out block. Similar reasoning applies to en$\operatorname{ter}$ (PRO,ENCLOSURE). At the other end of the hierarchy, the canonical events associated with physical object are predicted to be implausible ( large, $m$ small).

## Enjoy Garden

Mary enjoyed the garden (seeingivisiting)


## Enjoy rock

## TJohn enjoyod the rock



## Enjoy wine



## Where do classes come from?

## What's a natural word?

- NO: NALL = 'not all'
- NO: green and an hour long
- Nonconstituent: John ate pizza and Mary, bread = "Mary bread"


## A tree grows in Brooklyn



These are the ‘natural classes'

## Keil's predicability tree and conceptual 'naturalness'



## Bleaching - noun meaning bleached

a. John bosed the present
b. John PUT the present IN a <BOX>
c. John boxed the present in a gift box
d. \# John bosed the present in a brown paper bag
a. Maty buttered the piece of toast
b. Mary PUT <BUTTER> ON the piece of toast
c. Mary buttered the toast with margarine/unsalted butter
d. \#Mary buttered the toast with marmalade/onions

## More examples

a. Peter shelved a book
b. Peter shelved a book on the windowsill/mantelpiece/table/stand
c. \#Peter shelved a book on the ball/spike/ceiling/floor/balcony
a. Sue breaded the fish
b. Sue breaded the fish with breadcrumbs/shredded coconut/crushed almonds
c. \#Sue breaded the fish with marmalade/butter/treacle/ice
a. x PUT Y ON <SHELF>
b. x PUT y ON $z$ \& shelf-like-object(z)
a. \# X PUT <BREAD> ON y
b. XPUT crumbs of <BREAD $>O N$ y
c. X PUT crumbs of $z$ ON $y$

## Wordnet hypothesis

Denominal root Y may be bleached using X if
a. X is a hyponvm" of Y , or
b. Z is a functional hypernym ${ }^{+}$of Y , and X is a hyponym ${ }^{+}$of Z

## Path from shelf to windowsill


(a)

(b)

## More about shelf



## Blanket


blanket $_{2}$ isa covering ${ }^{\text {isa }}$ - natural objoct

# What information is in the lexicon? 

/shelf/ vs. /put/ vs. /butter/

/put/,/shelf/ imposes $p_{\text {location }}$ on arguments /put/, /butter/ imposes pocatum on arguments

## Hypothesis 1: Lexicon Contains Selection Criteria

/shelf/ has $p_{\text {tocartion }}$ selection in lexicon ( $=\mathrm{p}_{\text {Locartron }}=\mathrm{d}(\mathrm{et}) \mathrm{v}$ ) Also: /shelf/ is $n_{\text {Locartow }}$
/butter/ has $\mathrm{p}_{\text {iocartum }}$ selection in lexicon ( $=\mathrm{p}_{\text {iocartum }}=\mathrm{d}(\mathrm{et}) \mathrm{v}$ )
Also: /butter/ is $n_{\text {rocarum }}$
So then the Lexicon cannot derive:

* 1. Bob shelved the windowsill with the book.
* 2. Bob buttered the margarine onto the bread.

Information about butter and shelf - where is it located?

## Hypothesis 1 Problem

| 00 | How does lexicon acauire the |  |
| :---: | :---: | :---: |
| following: |  |  |
| /shelf/ | niocation | $=\mathrm{p}_{\text {LUCAIIUN }}=\mathrm{d}$. V |
| /butter/ | $\mathrm{n}_{\text {Lentur }}$ | $=\mathrm{p}_{\text {den }}=\mathrm{d} \mathrm{V}$ |
| /shovel/ | $\mathrm{n}_{\text {INSI-MO1 }}$ | $=\mathrm{p} \quad=\mathrm{p} \quad=\mathrm{d} \mathrm{V}$ |
| / | $\mathrm{n}_{\text {tictame }}$ |  |
| /mop/ | $\mathrm{n}_{\text {INSI-REMIVVAL }}$ | $=\mathrm{n}_{\text {INSIT-REMMOVAL }}=\mathrm{n}_{\text {SOURCE }}=\mathrm{d}$ - V |
| /email/ | $\mathrm{n}_{\text {INST-COMM }}$ | $\mathrm{p}_{\text {INST-COMM }}=\mathrm{p}_{\text {HAVE }}=\mathrm{dV}$ |
|  |  | $\mathrm{P}_{\text {INST-COMM }}=\mathrm{P}_{\text {DEST }}=0$ |

Solution 1: Solve the above problem
Solution 2: Push problem OUT of Lexicon and

## Solution 2: Push problem OUT of Lexicon and INTO Encyclopedia

Encyclopedia, not lexicon, is source of 'Oddness' of:
\# (1) Bob shelved the windowsill with the book.
\# (2) Bob buttered the margarine onto the bread.
Lexicon is NOT:
/shelf/ $=p_{\text {LOCATION }}=d$ (et) $V \quad / b u t t e r /=d+k p_{\text {LOCATUM }}$
/into/ =d +case $p_{\text {LOCATION }} \quad / w i t h /=d$ +case $p_{\text {LOCATUM }}$
But instead:
/shelf/ =p =d v /butter/ =d +case p
/into/ =d +case p /with/ =d +case p
Thus insofar as the lexicon is concerned, (1) and (2) are GRAMMATICAL.

## Encyclopedia vs. Lexicon

| ROOT | Lexicon | Examples |
| :---: | :---: | :---: |
| arrive | +v, +DP, -cause | John-arrived. The arrival_of John |
| big | $-\mathrm{v}, ~+\mathrm{DP}$ | The big $X$. |
| open | $\pm \mathrm{v}$, +DP, $\pm$ cause | John-opened $X$, $X$-opened. |
| destroy | +v, +DP, +cause | Jمhn destroyed X John's destruction of $X$ |
| grow | +v, +DP, $\pm$ cause | Tomatoes grew. John grew tomatoes. lohn's growth of tomatoes. |

Encyclopedia holds knowledge 'rejecting' the following GRAMMATICAL sentences:
\# John thought the book to Mary \# John's growth of tomatoes
\# Sue walked in an hour
\# Bob shelved the windowsill with the book.
\# Bob buttered the margarine onto the bread.

## 2 Language Acquisition Problems: Lexicon vs Encyclopedia

| ROOT | LEXI CON ENTRIES |
| :--- | :--- |
| $/$ shelf/ | $\mathrm{n},=\mathrm{p}=\mathrm{d} \mathrm{V}_{\text {+cause }}$ |
| $/$ butter/ | $\mathrm{n},==\mathrm{d} \mathrm{V}_{\text {+cause }}$ |
| /into/ | $=\mathrm{d}+\mathrm{k} \mathrm{p}$ |
| $/$ with/ | $=\mathrm{d}+\mathrm{k} \mathrm{p}$ |

## LEXICON ACQUISITION:

How do LEXICAL roots get assigned to feature set?

| ROOT | ENCYCLOPEDIA ENTRIES |
| :---: | :---: |
| /shelf/ | $\mathrm{n}_{\text {Locarion }},=\mathrm{p}_{\text {Iocarion }}=\mathrm{d} \mathrm{V}$ |
| /butter/ | $\mathrm{n}_{\text {Locarum }}=\mathrm{P}_{\text {LiocatuM }}=\mathrm{d} \mathrm{V}$ |
| /into/ | $=\mathrm{d}+\mathrm{k} \mathrm{P}_{\text {Locartow }}$ |
| /with/ | $=\mathrm{d}+\mathrm{k} \mathrm{p}_{\text {tocarum }}$ |

## ENCYCLOPEDIA ACQUISITION:

How do ENCYCLOPEDIA roots
get assigned to feature set?

## Predicate-arguments to thematic roles

- Use linking rules
- These say whether, e.g, Subject is the agent...
- Is there a theory for this?
- How do we build this knowledge?


## Predicate-argument structures for lose

losel (Agent: animate, Patient: physical-object)
lose2 (Agent: animate,
 Patient: competition)

Agent <=> subj
Patient <=> obj

## Machine Translation Lexical Choice- Word Sense Disambiguation

Iraq lost the battle.
Ilakuka centwey ciessta.
[Iraq ] [battle] [lost].

John lost his computer.
J ohn-i computer-lul ilepelyessta.
[John] [computer] [misplaced].

# Word sense disambiguation with Source Language Semantic Class Constraints (co-occurrence patterns) 

lose1(Agent, Patient: competition) <=> ciessta
lose2 (Agent, Patient: physobj) <=> ilepelyessta

## Is there enough data?

- Break


## Levin classes ( 3100 verbs)

- 47 top level classes, 150 second and third level
- Based on pairs of syntactic frames.

John broke the jar. / Jars break easily. / The jar broke.
John cut the bread. / Bread cuts easily. / *The bread cut.
John hit the wall. / *Walls hit easily. / *The wall hit.

- Reflect underlying semantic components contact, directed motion, exertion of force, change of state
- Synonyms, syntactic patterns, relations


## Another alternation example

- Another example: Causative/inchoative
- The window broke
- John broke the window
- The rabbit suddenly appeared
- *The magician appeared the rabbit
- Benefactive:
- Sue carved a toy out of wood for Hansel
- Sue carved hansel a toy out of wood
- Sue carved some wood into a toy for Hansel
- *Sue carved Hansel some wood into a toy
- Middle formation:
- The whale frightens easily
- *The whale sees easily


## Alternations..

- Sue broke the vase/ The vase broke (change-of-state)
- The vase broke easily
- Conative: *Sue broke at the vase
- Bill cut the bread/ *The bread cut (change-of-state, no "telic" endpoint)
- The bread cut easily
- Bill cut at the bread
- Mary touched the cat / *The cat touched
- *The cat touched easily (no change-of-state)
- *Mary touched at the cat
- J oe kicked the tire / *The tire kicked
- *The tire kicked easily
- Joe kicked at the tire
- Alternations can be lang-specific: "break" is a causative/inchoative in English, but not Italian.


## Break Levin class - Change-of-state



Lexical Gaps: English to Chinese
break
?
smash
shatter

da po - irregular pieces
da sui - small pieces
pie duan -line segments
snap


## Intersective Levin classes



## So we want...



## Thematic Roles

- E w, x,y,z Giving (x) ^ Giver(w, x) ^ Givee(z, x) ${ }^{\wedge}$ Given $(\mathrm{y}, \mathrm{x})$
- E w,x,z Breaking (x) ^ Breaker(w, x) ^ Broken( $z, x$ )
- A set of roles:
- agent, experiencer, force, theme, result, content, instrument, beneficiary, source, goal,...
The dog ate the cheeseburger. What is cheeseburger?
The sniper shot his victim with a rifle. What is rifle?


## Schank's Conceptual Dependency

- Eleven predicate primitives represent all predicates
- Objects decomposed into primitive categories and modifiers
- But few predicates result in very complex representations of simple things
Ex,y Atrans(x) ^ Actor(x, John) Object $(x$, Book $) ~ \wedge ~ T o(x, M a r y) ~ \wedge ~ P t r a n s(y) ~ へ ~$
Actor $(\mathrm{y}, \mathrm{John}) ~ \wedge ~ O b j e c t(y, B o o k) ~ \wedge ~ T o(y, M a r y) ~$
John caused Mary to die vs. John killed Mary


## Selection via sortal hierarchy

- John ate a clam
- They served clams
- "logical" form: $\exists \mathrm{x}, \mathrm{y}, \mathrm{e}$ [eat(e) \& eater(e, y$)$ \& eaten(e, x) \& john(y) \& clam(x) \& past(e)]
- So...


## Sortal hierarchy ('ontology’)


food implement

## Selection via sortal hierarchy

1. eater([Eating],[Being])
2. eat([Eating])
3. eaten([Eating],[Food])
4. server([Serving],[Being])
5. serve ${ }_{1}($ Serving $\left.]\right)$
6. served([Serving],[Food])
7. john([Person])
8. they([Person])
9. mussel $_{1}$ ([Food])
10. mussel $_{2}($ [Creature])

## But...

- Which airlines serve Denver?
- You ate glass on an empty stomach
- Metonomy: What airlines fly to Boston?


## But how can we/computer learn this?

- Two parts: pred-arg linking to thematic roles - which verbs do what
- Selectional restrictions


## pour vs. fill

- Different linking entails semantic difference when in Object position, the Goal seems "affected" in a way not so in the PP
- Fill: Cause $X$ to become full of $Y$ by means of causing $Y$ to be in $X$
- Pour: Cause $X$ to go in a downward stream into $Y$
- Fill has two events: a state change (the glass) and a location change (the water)
- Pour has one event: location change
- The Main-change argument gets Old-Info structure and main event status. Main event of Fill: state change of glass



## Two Bootstrapping Proposals

- Children use syntactic cues to verb meaning (Gleitman 1990)
- Children use (verb) meaning to figure out how its arguments are realized in the syntax of the language (Pinker 1989)


## Semantic Bootstrapping <br> (Pinker 1984)

Semantic Bootstrapping involves the pairing of a situational context with some syntactic pattern.

- Kids learn syntax by first learning the semantic argument structure of the verb.
- SWIM = one participant (the "swimmer")
- EAT = two participants ("eater", "eatee")
- TAKE = two/three participants ("taker", "takee", and "person taken from"...)


## Gleitman: Not So Fast, Pinker...



Temporal ambiguity


Situation ambiguity


Mental unobservable!
... more than just real-world observation...
6.863J/9.611J Lecture 15 Sp 03

## Syntactic Bootstrapping

(Landau and Gleitman 1986, Naigles 1990)
Syntactic frames provide evidence for meaning:

$H_{1}$ : arm wheel

$\mathrm{H}_{2}$ : cause to squat


## Verbs Classes Grouped by Cause Feature

| $\mathrm{H}_{\mathrm{i}} \quad$ Verb Class <br> Externally Caused (touch, load) <br> F1: He touched the glass. <br> * FO: The glass touched. |
| :---: |
|  |  |
|  |
| $H_{*}$ Externally Causable (open, break) <br> F1: He opened the door. <br> F0: The door opened. |
|  |

One-shot learning
within a Bayesian framework.


Prior: $p\left(H_{i}\right)$
Acquired Lexicon
Likelihood $p\left(x \mid H_{i}\right) \quad$ (/seb/meansPosterior: )

$$
p\left(H_{i} \mid x\right)
$$

## Learning Value of Verbs Cause Feature



| $\frac{\text { Syntactic Evidence } X \text { : }}{\text { /He glipped the balloon/ }}$ |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| /He glipped the balloon/ /X gorped Y/, /X gorped Y/ |  |  |  |  |
|  |  |  |  |  |
| Suntactic Theorv: $\quad / Y$ foomed $/{ }^{6}$ |  |  |  |  |
|  |  |  |  |  |
| $\underline{\mathbf{H}=\left\{H_{l}, H_{0}, H_{*}\right\}} \quad$ Bavesian L |  |  |  |  |
| Prior $p\left(H_{i}\right)$ |  |  |  |  |
| Likelihood $p\left(x \mid H_{i}\right)$ |  |  |  |  |
| Acquired Syntactic Knowledge |  |  |  |  |
| Lexicon: | Evidence $X$ | $\boldsymbol{p}^{\left(H_{l} \mid \boldsymbol{X}\right)}$ | $\boldsymbol{p}\left(\mathrm{H}_{0} \mid \boldsymbol{X}\right)$ | $\boldsymbol{p}\left(\boldsymbol{H}_{*} \mid \boldsymbol{X}\right)$ |
| /glip/ | F1 | . 633 | . 033 | . 333 |
| /gorp/ | F1, F1 | . 781 | . 002 | . 217 |
| /seb/ | F1, F0 | . 137 | . 137 | . 724 |
| /meef/ | $F 1^{5}, F 0$ | . 712 | 5e-6 | . 288 |
| /foom/ | $F 0^{6}{ }_{6.863 / 9.611]}$ | $2 e-8$ | . 979 | . 021 |

## Bayesian Learning at the SyntaxSemantics Interface



Acquired Lexicon $p(H i \mid x)$ $p($ POUR $/ x) p($ FILL $/ x) \quad p($ MOVE $/ x)$

## How to get 'real semantics' in?

