6.863J Natural Language Processing
Lecture 14: Word semantics I

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The Menu Bar

- Administrivia:
- Lab 4 due April 9
- *Agenda:*
- Lexical semantics: the meanings of words: how hard can it be?
- Tense and time (if there's time)

Word sense

- The benevolent alien race that visits earth.
- Their great book is entitled *How to Serve Humans*

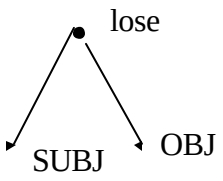
Predicate-arguments to thematic roles

- 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*

lose1 (*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.
John-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..

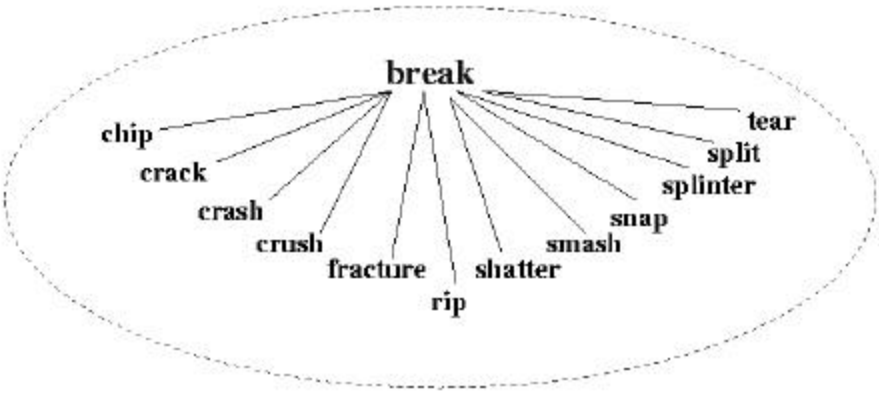
- Sue broke the vase/ The vase broke (change-of-state)
- The vase broke easily
- Conative: *Sue broke at the vase

- Bill cut the bread/ *The bread cut (change-of-state, no “telic” endpoint)
- The bread cut easily
- Bill cut at the bread

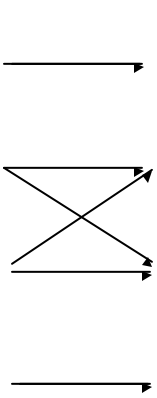
- Mary touched the cat / *The cat touched
- *The cat touched easily (no change-of-state)
- *Mary touched at the cat

- Joe 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



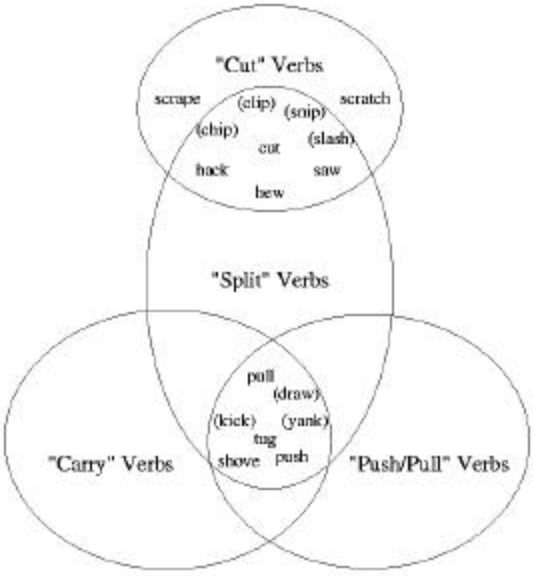
break → **?**

smash → da po - *irregular pieces*

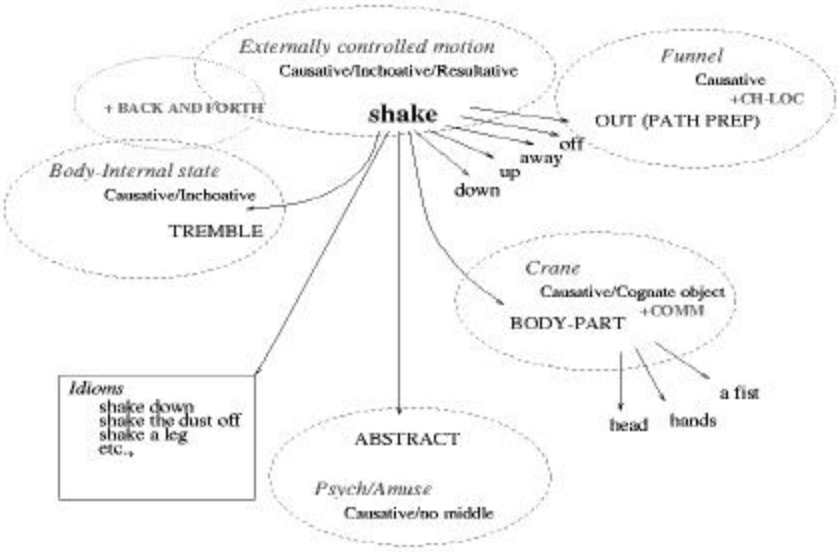
shatter → da sui - *small pieces*

snap → pie duan -*line segments*

Intersective Levin classes



So we want...



Thematic Roles

- E w,x,y,z Giving (x) ^ Giver(w,x) ^ Givee(z, x) ^ Given(y,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

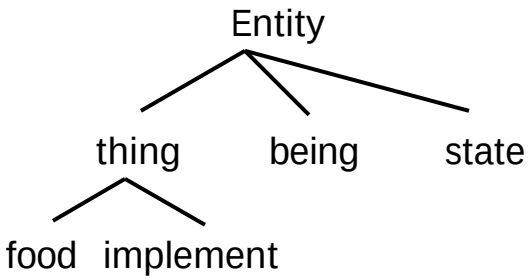
  Ex,y Atrans(x) ^ Actor(x,John) ^
  Object(x,Book) ^ To(x,Mary) ^ Ptrans(y) ^
  Actor(y,John) ^ Object(y,Book) ^ To(y,Mary)

  John caused Mary to die vs. John killed Mary

Selection via sortal hierarchy

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

Sortal hierarchy ('ontology')



Selection via sortal hierarchy

1. eater([Eating],[Being])
2. eat([Eating])
3. eaten([Eating],[Food])
4. server([Serving],[Being])
5. $serve_1$([Serving])
6. served([Serving],[Food])
7. john([Person])
8. they([Person])
9. $mussel_1$([Food])
10. $mussel_2$([Creature])

But...

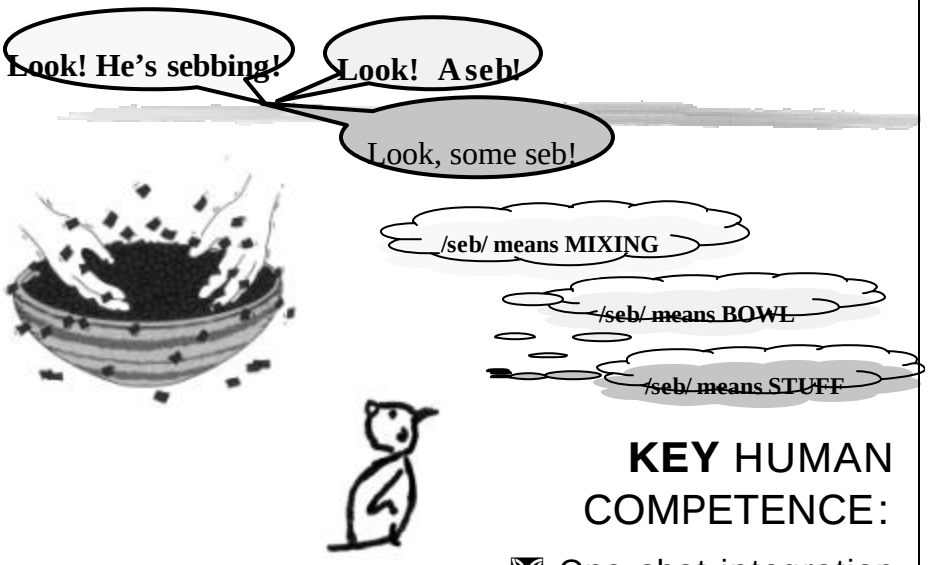
- Which airlines serve Denver?
- You ate glass on an empty stomach
- Metonomy: What airlines fly to Boston?

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



KEY HUMAN COMPETENCE:

- One-shot integration of syntax & semantics

The Problem of Ambiguity

Possible Hypotheses

- **Rabbit (whole object)**
- **Animal (superordinate)**
- **Flopsie (individual)**
- **Furry (property)**
- **Ear (part)**
- **Walk by (activity)**
- **Undetached rabbit parts .....**

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)

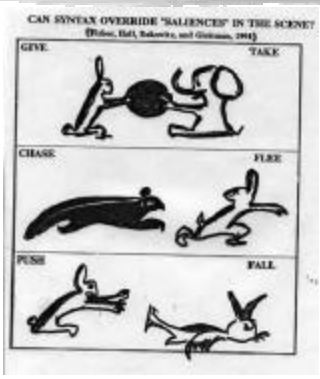
Semantic Bootstrapping

(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 <u>just</u> real-world observation...

Syntactic Bootstrapping

(Landau and Gleitman 1986, Naigles 1990)

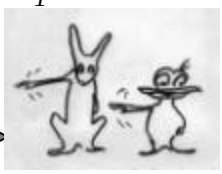
Syntactic frames provide *evidence* for meaning:

/X and Y are gorping!/

/Look, gorping!/

/X is gorping Y!/

H_1: arm wheel



H_2: cause to squat

Verbs Classes Grouped by Cause Feature

H_i	*Verb Class*
H_1	~~Externally Caused (*touch*, *load*)~~ *F1: He touched the glass.* ~~** F0: The glass touched.*~~
H_0	~~Internally Caused *(laugh, glimmer)*~~ ** F1: He laughed the child.* ~~*F0: He laughed.*~~
H_*	~~Externally Causable *(open, break)*~~ *F1: He opened the door.* ~~*F0: The door opened.*~~

***Hypothesis space* H**

Hi in H

Evidence x in X = {0, 1}

One-shot learning

within a Bayesian framework.

Syntactic Evidence ***Semantic Evidence*** | *Evidence x*

Linguistic Theory

BAYESIAN Acquisition Device

$p(H_i|x)=\frac{p(x|H_i)p(H_i)}{p(x)}$

$H=\{H_1, H_2, \ldots\}$
Prior: $p(H_i)$
Likelihood $p(x|H_i)$

Acquired Lexicon
(/seb/ means Posterior: $p(H_i|x)$ *)*

Learning Value of Verbs Cause Feature

Syntactic Evidence:
/He glipped the balloon/
x=F1

Syntactic Theory:
$\boldsymbol{H}=\{H_1, H_0, H_*\}$

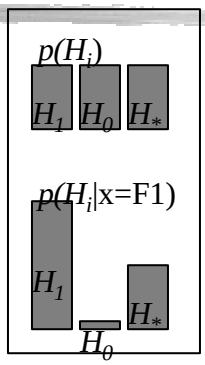
Prior:
$p(H_i) = .333$

$p(H_i|x)=\frac{p(x|H_i)p(H_i)}{p(H_i)}$

Likelihood $p(x|H_i)$

	x=F0	x=F1
H_1	.05	.95
H_0	.95	.05
H_*	.50	.50

Acquired Lexicon
Posterior $p(H_i|x)$
$p(H_1|x=F1) = .633$
$p(H_0|x=F1) = .033$
$p(H_*|x=F1) = .333$



$= \frac{(.95)(.33)}{(.05+.95+.50)(.33)}$

Syntactic Evidence X:

/He glipped the balloon/
/X gorped Y/, /X gorped Y/
/X sebbed Y/, /Y sebbed/
/X meefed Y/[5], /Y meefed/
/Y foomed/[6]

Syntactic Theory:

H=$\{H_1, H_0, H_*\}$
Prior $p(H_i)$
Likelihood $p(x|H_i)$

Bayesian Language Acquisition Device

Acquired Syntactic Knowledge

Lexicon:	***Evidence X***	$p(H_1\|X)$	$p(H_0\|X)$	$p(H_*\|X)$
/glip/	*F1*	*.633*	*.033*	*.333*
/gorp/	*F1, F1*	*.781*	*.002*	*.217*
/seb/	*F1, F0*	*.137*	*.137*	*.724*
/meef/	*F1*[5], *F0*	*.712*	*5e-6*	*.288*
/foom/	*F0*[6]	*2e-8*	*.979*	*.021*

Bayesian Learning at the Syntax-Semantics Interface

Syntactic Evidence
/X is gorping Y into Z/
/X is pilking Z with Y/
/Look! jebbing!/

Semantic Evidence
Person pours water into a glass, filling it
Person pours water into a glass, filling it
Person pours water into a glass, filling it

Linguistic Theory
$H=\{H_1, H_2, \ldots\}$
Prior: $p(H_i)$
Likelihood $p(x|H_i)$

Bayesian Language Acquisition Device

Acquired Lexicon $p(Hi|x)$

	$p(POUR\|x)$	$p(FILL\|x)$	$p(MOVE\|x)$
/gorp/	***.880***	*.000*	*.101*
/pilk/	*.001*	***.989***	*.000*
/jeb/	***.463***	***.463***	*.005*

How to get ‘real semantics’ in?

Verb meanings are logic programs (LPs):

General:	cause(e)
One args x:	move(x), rotate(x), move-dn(x), move-up(x) supported(x), liquid(x), container(x)
Two args x,y: (if cause(e)=1)	contact(x,y), support(x,y), attach(x,y)

Verb	**Logic Program**
/lower/	1 1*101** 11*
/raise/	1 1*011** 11*
/rise/	0 1*01***
/fall/	0 1*10***

Hypothesis space **H**: All LPs
Evidence *X*: Bit Vector Examples
(e.g. 1 1010100 110)

Learning Semantic Features

Semantic "Theory": (3 bits)

Hypothesis space **H**: 27 LPs

q	H_i
0	000, 001, 010, 011
	100, 101, 110, 111
1	00*, 01*, 10*, 11*
	0*0, 0*1, 1*0, 1*1
	*00, *01, *10, *11
2	0**, 1**, *0*, *1*, **0, **1
3	***

Priors $p(H_i) = 1/27$

Likelihood $p(x|H_i) = \{2^{-q}$ if x in H_i

$p(x{=}000|H_{000}) = 1$
$p(x{=}000|H_{00*}) = .5$
$p(x{=}000|H_{0**}) = .25$
$p(x{=}000|H_{***}) = .125$

Semantic Evidence:

/Look! Glipping!/ X1=000
/Look! Gorping!/ X2=000,001
/Look! Sebbing!/ X3=000,000,000
/Look! Meefing!/ X4=000,101,010,111,000

Acquired Semantic Knowledge

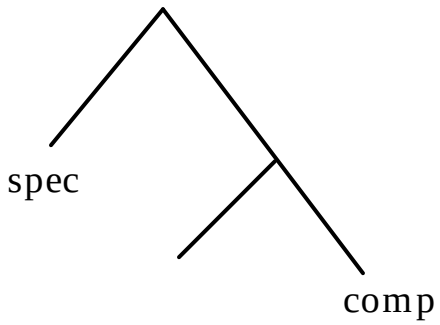
Lexicon:	$p(H_{000}\|X)$	$p(H_{00*}\|X)$	$p(H_{0**}\|X)$	$p(H_{***}\|X)$
/glip/	*.30*	*.15*	*.07*	*.03*
/gorp/	*.00*	*.64*	*.16*	*.04*
/seb/	*.70*	*.09*	*.01*	*.001*
/meef/	*.00*	*.00*	*.00*	*1.0*

But... what are the possible arguments?

- Predicate-arguments can be complicated...can we crank it out?
- Argument structure is syntax
- There are no specialized mechanisms of 'thematic role assignment'
- Everything is really predication

Hale-Keyser: arguments are syntax

The basic form



H & K: The framework

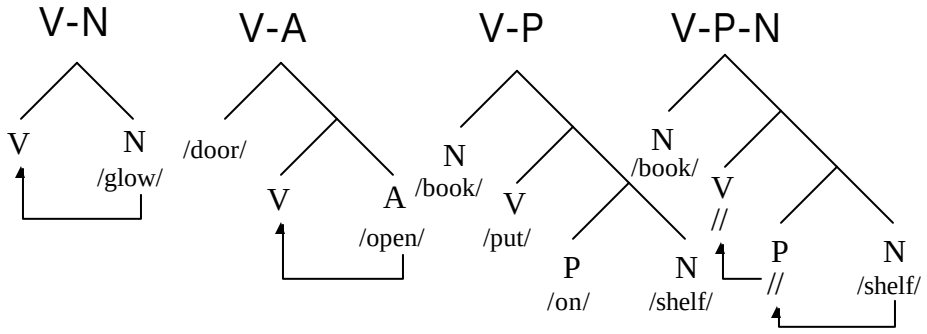
- There are only three places a verb argument can come from
  - The complement or specifier of a “basic” lexical item
  - An external “addition”
  - As for “basic lexical items” there are four types: N, V, A, P
  - Why so few thematic roles? Because so few basic lexical items (entity/instance, event, state, relation)

N,V,A,P

- N takes no arguments
- V are predicational, and take one argument, a complement.
- P are relational, and take two arguments
- A are predicational, and take one argument, but require some help; thus an A is always the complement of a verb, which then projects for an external arg.

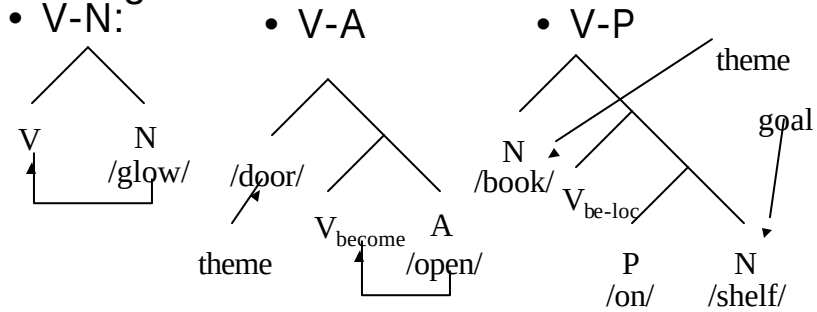
Hale-Keyser Incorporation

- 4 Fundamental Primitives Yield Different Argument Structures



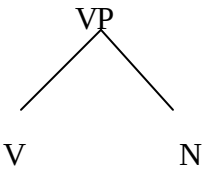
HK Allows Us to Discard Thematic Roles

- Agent, Patient, Theme, Instrument, Goal, ... *derived* from positions in structural configurations.



What can N get us?

- Intransitive verbs:



Nouns cannot project arguments. A noun (run, laugh, play, cough, snore, burp) incorporates into the verb. An external argument is adjoined to *v*. Thus, rather than having cognate N and V copies in the lexicon, verbs are derived by *syntax*.

Unergatives vs. Simple Transitives

- Unergatives: no external agent *The child laughed*
  - [NP [*v* [V+N (N)]]]
- No verbs like **The clown laughed the child* / **The alfalfa sneezed the colt* (The N complement to V has incorporated, where would the "object NP" reside?)
  - [NP [V+N (N) NP?]]
- Simple transitive (non-creation) *The clown made the child laugh*
  - [NP [*v* [NP [V+N (N)]]]]
  - Extensions : *get+A (I got drunk, I got Josh drunk)*
    - But not for get+N (*I got the measles, *I got Josh the measles*)

Explaining Gaps in the Lexicon

- *It cowed a calf, *It dusted the horses blind, *It machined the wine into bottles (cf. The cow had a calf, the dust made the horses blind, the machines put the wine into bottles)
- The above items would be the result of the external subject incorporating into the verb, which is ruled out by the syntax elsewhere (items raise & incorporate up, but not down)
- If all "denominal" verbs are the result of incorporation of the complement to the V head, rather than unconstrained "category change", these non-verbs are predicted

V: Verbs of Creation: The simple case

- bake a cake, make trouble, build a house, have puppies
- V has a complement NP(=DP). External argument is projected and adjoined to *v.*

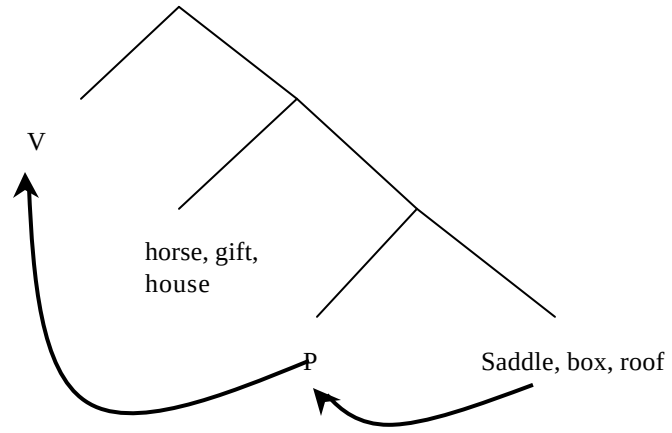
P gives *put*-type Verbs

- The P frame has a specifier and complement. The whole P-complex is a verb complement. An external argument is projected and adjoined.

P gives locatum-type verbs

- With a bare N as the PP complement, the N conflates with the P, which conflates with the V, giving *saddled the horse, boxed the gift, roofed the house* (all have P-meaning)

Picture



Implementation

```
(define-verb-class "PUT VERBS: put verbs (Section 9.1)"
  "putting entity at some location (but not to or from)"
  '(arrange immerse install lodge mount place position put set
    situate sling stash stow)
  (list '((* the water put into a bowl))
        '((+ he put the water into the bowl)
          (vp ()
              (v* (v put (feature CAUSE))
                  (pp (n the water)
                      (p* (p into (feature MOVELOCATION))
                          (n a bowl))))))))
```

Argument Structure: The Moral

- No specialized mechanism of “thematic role assignment”. Everything is predication.
- Do these mechanisms of derived verbs happen in the syntax with everything else, or “prior to lexical insertion”, e.g. “in the lexicon”? What do you think? Should this distinction *matter*?