Semantics and Pragmatics of NLP
Lexical Semantics: Polysemy

Alex Lascarides

School of Informatics
University of Edinburgh
Outline

1. Why A Dictionary Won’t Do: Polysemy!
2. Different Kinds of Polysemy
3. How to Capture Lexical Generalisations
Basic Lessons

- The meanings of words sometimes predict aspects of their syntactic behaviour (regular polysemy).
- So lexical knowledge is the interface between world knowledge and linguistic knowledge/processing.
- Discourse/ pragmatic processing interacts with lexical semantics.
- Lexical semantic information can be modelled using a typed feature structure formalism, extended to handle defaults.
Introducing *bake*

(1) a. Kim is baking  
b. The potatoes are baking  
c. Kim is baking a cake  
d. Kim is baking a cake for Sandy  
e. Kim is baking Sandy a cake  
f. The clay baked  
g. The clay baked hard  
h. Sandy was baking, sitting in the hot sun
Sense enumeration: a strawman

(2)  

a. \( \langle \text{bake}, \text{TakesNP}, \text{bake}'_1 \rangle \)  
b. \( \langle \text{bake}, \text{TakesNP}, \text{bake}'_2 \rangle \)  
c. \( \langle \text{bake}, \text{TakesNP.NP}, \text{bake}'_3 \rangle \)  
d. \( \langle \text{bake}, \text{TakesNP.NP.PP}, \text{bake}'_4 \rangle \)  
e. \( \langle \text{bake}, \text{TakesNP.NP.NP}, \text{bake}'_5 \rangle \)  

Senses connected by *meaning postulates*, such as:

- \( \forall x, y[\text{bake}'_3(x, y) \rightarrow \text{bake}'_1(x) \land \text{bake}'_2(y)] \)  
- \( \forall x, y[\text{bake}'_4(x, y, z) \rightarrow \text{bake}'_3(x, y)] \)
Problems

- Doesn’t capture generalisations (cf *cook*, *paint*)
- No distinction between homonyms (accidental polysemy) and related senses
- Meaning postulates are unrestricted
- Cannot list all potential usages.
Terminology

homonymy  *mogul*: mound of snow vs. *mogul*: Chinese emperor

unpredictable polysemy  *bank*: tilt of plane vs. *bank*: mound

regular polysemy  *bank*: building used by *bank*: institution

nonce  not recorded in the lexicon, but interpretable via generative devices;

*The ham sandwich is getting impatient.*

institutionalised  recorded in the lexicon as derived by a regular process; *teacher*

lexicalised  idiosyncratically augment or override regularly derived information; *in hospital.*

established  covers *institutionalised* and *lexicalised*
**More Terminology**

**constructional polysemy** a single sense assigned to a lexical entry is contextually specialised

(3)  
- a. That book is 500 pages long  
- c. That book is 500 pages long and introduces syntax.

**sense extension** separate lexical entries are generated

(4)  
- a. That chicken is healthy.  
- b. That chicken is tasty.  
- c. That chicken is healthy and tasty.

Distinction between constructional polysemy and sense extension is not always clear cut.
Back to the lexical entry for transitive *bake*

HPSGish syntax and MRS — neutral wrt various approaches to lexical semantics
**Different Kinds of Polysemy**

### How to Capture Lexical Generalisations

**bread (NP)**

\[
\begin{align*}
\text{phrase} & : \text{bread} \\
\text{ORTH} & : \text{bread} \\
\text{SYN} & : \begin{cases} 
\text{CAT} : n \\
\text{SUBCAT} : \langle \rangle 
\end{cases} \\
\text{INDEX} & : [w] \\
\text{SEM} & : \begin{cases} 
\text{LISZT} & : \langle \text{bread_rel}, \text{INST} : [w] \rangle 
\end{cases} \\
\end{align*}
\]

LISZTs are appended when signs are combined

\[
\text{BAKE_3}(e, x, y) \land \text{BREAD}(y)
\]

[Alex Lascarides] SPNLP: Lexical Polysemy
transitive-verb
ORTH : bake

CAT : v
SUBJ : NP

SUBCAT : ⟨NP x⟩

INDEX : e

SEM :

LISZT : ⟨_bake3_rel
EVENT : e
ARG1 : x
ARG2 : y⟩
Type for simple transitive verbs

Generalisation: agents realised as subjects and patients as objects.
Information on higher types is inherited by lower types (and lexical entries, such as bake3)

Multiple inheritance is possible
(5) a. Sandy enjoyed the film/beer/hamburger.
b. Sandy enjoyed the book.
c. Sandy enjoyed reading the book
d. The goat really enjoyed your book.

Don’t want to enumerate a million senses of *enjoy*!

It’s not a purely pragmatic phenomenon:
??John enjoyed the doorstop. ??John enjoyed the tunnel.

Generalisation: When *NP* is an artifact, *enjoy NP* means *enjoy V-ing NP*, where *V* is its purpose.

But this can be overridden in sufficiently rich discourse contexts.
Capturing the Generalisation (Simplified): enjoy the book

book:
- **book**: \(\text{book}(y)\)
- **SEM**: \(\text{book}(y)\)
- **QUALIA**: \(\text{Const} : \text{pages} \), \(\text{Telic} : \text{read} \), \(\text{Agentive} : \text{write} \)

enjoy: inherited info; \(\text{begin}, \text{finish}\) etc.
- **coercing**: \(<\text{np}\) SEM : \(\text{n}\) [\(\text{Q}(y)\)]
- **CAT SUBCAT**: \(<\text{QUALIA Telic} : \text{act-on-pred} \ P\)
- **SEM**: \([e][\text{enjoy}(e, x, e') \land \text{act-on-pred} / \ P (e', x, y) \land \text{n} \text{book}(y)]\)

enjoy the book:
- **coercing**: \(<\text{np}\) SEM : \(\text{n}\) [\(\text{Q}(y)\)]
- **CAT SUBCAT**: \(<\text{QUALIA Telic} : \text{act-on-pred} \ P\)
- **SEM**: \([e][\text{enjoy}(e, x, e') \land \text{act-on-pred} / \ P (e', x, y) \land \text{n} \text{book}(y)]\)
Construcional Polysemy: Sense Broadening

(6)  
a. There are clouds in the sky — it’s going to rain.  
b. There was a cloud of flies round the cow.  
c. The flies were pestering the horse — it swished its tail at the buzzing cloud.

lex-count-noun
ORTH : cloud
CAT : noun-cat
SEM : obj-noun-formula

QUALIA : 
FORM : 
RELATIVE : indiv
ABS. : amorph
CONSTITUENCY : phys_cum / water-vapour
Sense extension

- Grammatical effects: count $\rightarrow$ mass, verbing
- Established and non-established senses
- Conventional nature of process

(7) a. Sandy drank a bottle of whisky.
   container $\rightarrow$ contents
b. Sandy drank a bottleful of whisky.

(8) a. Kim ate some chicken.
   animal $\rightarrow$ meat
b. That restaurant serves ostrich.
A particular kind of Sense Extension: Reference Transfer

(9) a. The ham sandwich has paid his check.
   physical object $\rightarrow$ associated person

b. *The dark haired guy is in the microwave.

(10) Chester serves not just country folk, but farming, suburban and city folk too. You’ll see Armani drifting into the Grosvenor Hotel’s exclusive (but exquisite) Arkle Restaurant and C+A giggling out of its streetfront brasserie next door. (Guardian Weekly)

manufacturer $\rightarrow$ product + clothes $\rightarrow$ wearer
"Lexical Rules"

grinding $<$ lexical-rule

$$
\begin{array}{|c|c|c|}
\hline
\text{LEX-COUNT-NOUN} & \text{ORTH} : 0 & \text{SYN} : \text{noun-cat} \\
\text{SEM PRED} : 3 & \text{QUALIA} : \text{physical} \\
\hline
\end{array}
\rightarrow
\begin{array}{|c|c|c|}
\hline
\text{LEX-UNCOUNT-NOUN} & \text{ORTH} : 0 & \text{SYN} : \text{noun-cat} \\
\text{SEM PRED} : \text{grinding}'(3) & \text{QUALIA} : \text{physical} \\
\hline
\end{array}
$$

meat-grinding $<$ grinding

$$
\begin{array}{|c|}
\hline
\text{QUALIA} : \text{animal} \\
\hline
\end{array}
\rightarrow
\begin{array}{|c|}
\hline
\text{QUALIA} : \text{edible_substance} \\
\hline
\end{array}
$$
Verb classes: Levin (1993)

Large-scale descriptive account of (some) English verbs, pushing the idea that syntactic behaviour is (partly) semantically determined

- alternations
  The ways in which arguments to verbs can be realised differently.
- semantically coherent classes which exhibit the same alternations
- some extended senses (eg *whistle* as a movement verb)
26 Verbs of Creation and Transformation

26.1 Build verbs

Class members include: bake, cook

(11) Material/Product Alternation (transitive):
   a. Martha baked a loaf out of wholewheat flour
   b. Martha baked some wholewheat flour into a loaf

(12) Unspecified Object Alternation:
   a. Martha bakes bread
   b. Martha bakes

(13) Benefactive alternation
   a. Martha baked a loaf (out of wholewheat flour) for her aunt
   b. Martha baked her aunt a loaf (out of wholewheat flour)
26.3 Verbs of Preparing

Class members include: bake, cook, fix, fry

(14) *Material/Product Alternation (transitive):
   a. ?Donna fixed a sandwich from last night’s leftovers
   b. *Donna fixed last night’s leftovers into a sandwich

(15) Benefactive alternation
   a. Donna fixed a sandwich for me
   b. Donna fixed me a sandwich

(16) *Causative alternations
   a. Donna fixed a sandwich
   b. *a sandwich fixed
45 Verbs of change of state

45.3 Cooking verbs  **Class members include:** bake, cook, fry

(17) Causative/Inchoative Alternation
    a. Jennifer baked the potatoes
    b. The potatoes baked

(18) Middle Alternation
    a. Jennifer baked Idaho potatoes
    b. Idaho potatoes bake beautifully

(19) Instrument Subject Alternation
    a. Jennifer baked the potatoes in the oven
    b. This oven bakes potatoes well
Representing alternations: Lexical rules

**creation-tverb**

ORTH: 

SYN: 

SEM: 

**benef-PP-verb**

ORTH: 

SYN: 

SEM: 

John baked a cake → John baked a cake for Mary
Semi-productivity

*??pig* meaning meat, *??cow* meaning meat, *??John donated Oxfam a covenant* etc.

**Avoid obscurity**: use the form which has highest probability.

**Estimating Probabilities**: via \( \text{Prob(lexical-entry} \mid \text{word-form)} \)

**Seen lexical entries**: Use frequencies in a very large corpus (marked with senses!!)
- *badger* count noun, *deer* count noun.

**Unseen lexical entries**: Estimate the productivity of the appropriate lexical rule.
- *badger* meaning meat, *deer* meaning meat.
1. Estimate the degree of productivity of a lexical rule \( lr \) by comparing the number of attested outputs \( M_{lr} \) with the number of attested inputs \( N_{lr} \) seen in the corpus:

\[
\text{Prod}(lr) = \frac{M_{lr}}{N_{lr}}
\]

2. Use the \( \text{Prod}(lr) \)s to smooth over unseen data.

\[
\text{unseen-pr-mass}(wf) = \frac{\text{number-of-unattested-entries}(wf)}{\text{freq}(wf) + \text{number-of-unattested-entries}(wf)}
\]

\[
\text{est-freq}(le_i|wf) = \text{unseen-pr-mass}(wf) \times \frac{\text{Prod}(lr_i)}{\Sigma \text{Prod}(lr_1), \ldots, \text{Prod}(lr_n)}
\]
Blocking is an automatic consequence of **avoid obscurity**:

\[ \text{Prob}(\text{DEER-MEAT}|\text{venison}) > \text{Prob}(\text{DEER-MEAT}|\text{deer}) \]

therefore generation of blocked forms is marked.

(20) a. That restaurant serves venison/?deer.

b. There were five thousand extremely loud people on the floor eager to tear into roast cow with both hands and wash it down with bourbon whiskey. *(Terry Pratchett)*

Blocked forms dispreferred, but interpretable if other possibilities fail.

Need formal account of pragmatic effects of unblocking.
Conclusions

- Lexical semantics interacts in complex ways with syntax and pragmatics.
- A dictionary model of the lexicon is too simplistic to do this justice.
- But manually constructing a lexical type hierarchy with rich semantic information is impractical.
- Can we use machine learning from corpora to automatically acquire the lexical semantic information?
  - Next time: A case study—*logical metonymy*. 