Lecture 2. Theory Meets Corpus

- Enriching Composition Operations for More Explanatory Coverage
- Corpus Data on Semantic Transformations
- Lexical Sets and Corpus Pattern Analysis
Recall the Themes of this Course

- Language meaning is constructed compositionally
- Semantic theory constructs models over artificial data
- Compositionality must account for corpus data
- Corpus data must be annotated with existing theories
- Corpus phenomena force revisions and enrichments of theory.
What have we Learned thus far?

- Principle of Compositionality and Functional Typing
- The type of a verb is derived from the types of its arguments
- Argument selection is argument typing
Compositionality in Language

• One phenomenon we haven’t looked at yet...
Compositionality in Language

• One phenomenon we haven’t looked at yet...

• Logical Polysemy
Logical Polysemy

• When a single word or phrase has the ability to appear in selected contexts that are contradictory in type specification.

(62)a. Mary doesn’t believe the book.

a. **believe**: \( V(\text{human,proposition}) \)
   
   Apply believe(human,proposition) to [the book]

b. **sell**: \( V(\text{human,physobj,human}) \)
   
   Apply sell(human,physobj,human) to [the book]
Types in Generative Lexicon:

The Type Language

(63) a. $e$ the type of entities; $t$, truth values.

(b. If $\sigma$ and $\tau$ are types, then so is $\sigma \rightarrow \tau$;

c. If $\sigma$ and $\tau$ are types, then so is $\sigma \cdot \tau$;

d. If $\sigma$ and $\tau$ are types, then so is $\sigma \otimes_Q \tau$, for $Q =$

$\text{const}(c)$, $\text{telic}(t)$, or $\text{agentive}(a)$.
Qualia Structure as Types

(64) **TYPE FEATURE STRUCTURE:**

\[
\text{QUALIA} = \begin{bmatrix}
  x : \alpha \\
  \text{CONST} : \beta \\
  \text{FORMAL} : \alpha \\
  \text{TELIC} : \tau \\
  \text{AGENTIVE} : \sigma \\
\end{bmatrix}
\]
Qualia as Types

(65)

\[
\begin{pmatrix}
x : \alpha \\
\otimes_c \beta \\
\otimes_t \tau \\
\otimes_a \sigma \\
\end{pmatrix}
\]
Natural Entities

Entities formed from the application of the FORMAL and/or CONST qualia roles:

For the predicates below, $e_N$ is structured as a join semi-lattice, $\langle e_N, \sqsubseteq \rangle$;

(66)a. physical, human, stick, lion, pebble

b. water, sky, rock
Natural Entity Types as a Lattice

(67)
Natural Predicate Types

Predicates formed with Natural Entities as arguments:

(68)a. $\text{fall}: e_N \rightarrow t$

b. $\text{touch}: e_N \rightarrow (e_N \rightarrow t)$

c. $\text{be under}: e_N \rightarrow (e_N \rightarrow t)$

Expressed as typed arguments in a $\lambda$-expression:

(69)a. $\lambda x : e_N[\text{fall}(x)]$

b. $\lambda y : e_N \lambda x : e_N[\text{touch}(x,y)]$

c. $\lambda y : e_N \lambda x : e_N[\text{be-under}(x,y)]$
Artifactual Entity Types: $e_A$

Entities formed from the Naturals by adding the **AGENTIVE** or **TELIC** qualia roles:

(70) Expressed as types:

a. **Artifact Entity**: $x : e_N \otimes a \sigma$
   
   $x$ exists because of event $\sigma$

b. **Functional Entity**: $x : e_N \otimes t \tau$
   
   the purpose of $x$ is $\tau$

c. **Default Artifactual Entity**: $x : (e_N \otimes a \sigma) \otimes t \tau$
   
   $x$ exists because of event $\sigma$ for the purpose $\tau$
Artifactual Entity Types

Examples of types in $e_A$.

(71)a. **beer**: liquid $\otimes_t$ drink
    (liquid $\otimes_a$ brew) $\otimes_t$ drink (expressing Agentive)

b. **knife**: phys $\otimes_t$ cut
    (phys $\otimes_a$ make) $\otimes_t$ cut (expressing Agentive)

c. **house**: phys $\otimes_t$ live_in
    (phys $\otimes_a$ build) $\otimes_t$ live_in (expressing Agentive)
Human Functional Entity Types

(72) **TELIC** and **AGENTIVE** constraints on the Natural Type **HUMAN**:

a. *boss, friend;*

b. *dancer: human ⊗_t dance*

c. *wife, husband: human ⊗_a marry*
Artifactual Predicate Types

Predicates formed with Artifactual Entities as arguments:

(73)a. spoil: $e_N \otimes t \tau \rightarrow t$

b. fix: $e_N \otimes t \tau \rightarrow (e_N \rightarrow t)$

Expressed as typed arguments in a $\lambda$-expression:

(74)a. $\lambda x : e_A[spoil(x)]$

b. $\lambda y : e_A \lambda x : e_N[fix(x,y)]$

(75)a. The beer spoiled.

b. Mary fixed the watch.
Complex Entity Types

Entities formed from the **Naturals** and **Artifactuals** by a **product type** between the entities, i.e., the dot, ●.

(76)a. Mary doesn’t believe the book.

(77)a. John wrote the exam last night in under 10 minutes.
   b. The exam lasted more than three hours this morning.
Dot Objects: $e_C$

(78) Expressed as types:

a. Complex Entity: $x : e_i \bullet e_j$, for $i, j$ of any level

b. Complex Predicate: $P : x : e_i \bullet e_j \rightarrow t$
Wait a Second. . . Motivating Dot Objects

• When a single word or phrase has the ability to appear in selected contexts that are contradictory in type specification.

(79) If a lexical expression, $\alpha$, where $\sigma \sqcap \tau = \bot$:
   a. $[\_\_\_]_\sigma X$
   b. $[\_\_\_]_\tau Y$
are both well-formed predications, then $\alpha$ is a dot object (complex type).
Dot Object Inventory

1. Act•Proposition: promise, allegation, lie
   
   a. I doubt John’s promise of marriage.
   
   b. John’s promise of marriage happened while we were in Prague.
Dot Object Inventory

2. **State-Proposition**: belief
   a. Nothing can shake John’s belief.
   b. John’s belief is obviously false.
Dot Object Inventory

3. **Attribute•Value**: temperature, weight, height, tension, strength

a. The temperature is rising.
b. The temperature is 23.
Dot Object Inventory

4. Act•Proposition: promise, allegation, lie

a. I doubt John’s promise of marriage.

b. John’s promise of marriage happened while we were in Prague.
Dot Object Inventory

5. Event: Information: lecture, play, seminar, exam, quiz, test

a. My lecture lasted an hour.

b. Nobody understood my lecture.
Dot Object Inventory

6. Event•Human: appointment

a. You missed your last appointment.
b. Your next appointment is a Serbian student.
Dot Object Inventory

7. Event•Music: sonata, symphony, song, performance, concert

a. Mary couldn’t hear the concert.
b. The rain started during the concert.
Dot Object Inventory

8. **Event-Physical**: lunch, breakfast, dinner, tea
   
a. My lunch lasted too long today.
   
b. I pack my lunch on Thursdays.
Dot Object Inventory

9. **Information** • **Physical**: book, cd, dvd, dictionary, diary, mail, email, mail, letter

   a. Mary burned my book on Darwin.

   b. Mary believes all of Chomsky’s books.
Dot Object Inventory

10. **Organization**•(**Information**•**Physical**): magazine, newspaper, journal

   a. The **magazine** fired its editor.
   b. The cup is on top of **the magazine**.
   c. I disagreed with **the magazine**.
11. **Process→Result:** construction, depiction, imitation, portrayal, reference, rendering, decoration, display, documentation, drawing, enclosure, entry, instruction, design, invention, music, obstruction, pattern, simulation, illustration, agreement, approval, recognition, damage, compensation, contribution, disbursal, disbursement, discount, donation, acquisition, deduction, endowment, gift, categorization, classification, grouping

a. Linnaeus’s classification of the species took 25 years.
b. Linnaeus’s classification contains 12,100 species.
Reference to different Aspects of Dot Objects

(80)a. John read every book in the library.

(81)a. Mary answered every question in the class.
   b. Mary repeated every question in the class.
Introduces a coherence relation as a product type between a Natural, Artifactual, or Complex type, and reifies this as a type.

(82)a. *phys • info*: book, record, DVD;
   b. *event • event*: construction, examination;
   c. *phys • aperture*: door, window.
Complex Predicate Types

Predicates formed with Complex Entity Types as arguments:

(83) \( \text{read}: \text{phys} \bullet \text{info} \rightarrow (e_N \rightarrow t) \)

Expressed as typed arguments in a \( \lambda \)-expression:

(84) \( \lambda y : \text{phys} \bullet \text{info} \lambda x : e_N[\text{read}(x,y)] \)

(85) Mary read the book.
Enriching Compositionality

If all you have for composition is function application, then you need to create as many lexical entries for an expression as there are environments it appears in. (Weak Compositionality)

Two ways to overcome this:

(1) Type Shifting Rules: Partee-Rooth MG, CG, HPSG.
(2) Type Coercion Operations: GL, Hendriks, Moens and Steedman
Maintaining Compositionality

– Generative Mechanisms of Argument Selection:
  * Selection
  * Accommodation
  * Coercion:
    (i) Introduction
    (ii) Exploitation

– Qualia-based Type Structure:
  * Natural,
  * Artifactual,
  * Complex.
Generative Mechanisms of Argument Selection

– Pure Selection: The type a function requires is directly satisfied by the argument.
– Accommodation: The type a function requires is inherited by the argument.
– Coercion: The type a function requires is imposed on the argument type. This is accomplished by either:
  * Exploitation: selecting part of the argument’s type structure to satisfy the function’s typing;
  * Introduction: wrapping the argument with the type the function requires.
Type Coercion

– **Exploitation**: selecting part of the argument’s type structure to satisfy the function’s typing;

– **Introduction**: wrapping the argument with the type the function requires.
Two Kinds of Coercion in Language

– **Domain-shifting**: The domain of interpretation of the argument is shifted;
– **Domain-preserving**: The argument is coerced but remains within the general domain of interpretation.
Domain-Shifting Coercion

– Entity shifts to event:
  I enjoyed the beer

– Event shifts to interval:
  before the party started . . .

– Entity shifts to proposition:
  I doubt John.
Domain-Preserving Coercion

– **Count-mass shifting**: There’s chicken in the soup.
– **NP Raising**: Mary and every child came.
Domain-Preserving Coercion

– **Count-mass shifting**: There’s chicken in the soup.
– **NP Raising**: Mary and every child came.

Actually, they are all over the place:

– **Natural-Artifactual shifting**:
– **Natural-Complex shifting**:
– **Complex-Natural shifting**:
– **Artifactual-Natural shifting**:
– **Complex-Artifactual shifting**:
– **Complex-Complex shifting**:
– **Artifactual-Artifactual shifting**:
Function Application with Natural Types

Function Application: If $\alpha$ is of type $e_N$, and $\beta$ is of type $e_N \rightarrow t$, then $\beta(\alpha)$ is of type $t$.

A natural type tree:

```
    t
   / \  \
 e_N  e_N \rightarrow t
```
The rock fell.

(86)

Pure Selection: Natural Type

\[ \lambda x: e_N[fall(x)] \]
Pure Selection: Natural Type

The rock fell.

(87)
Function Application with Artifactual Types

**Function Application:** If $\alpha$ is of type $e_A$, and $\beta$ is of type $e_A \rightarrow t$, then $\beta(\alpha)$ is of type $t$.

**An artifactual type tree:**

```
    t
   / \   /
  e_A  e_A \  t
```


Pure Selection: Artifactual Type

The beer spoiled.

(88)

\[
S \\
\sigma \otimes_T \tau \\
NP \\
liquid \otimes_T drink : e_A \\
VP \\
the beer \\
spoiled \\
\lambda x : e_A[\text{spoil}(x)]
\]

\[
liquid \otimes_T drink \sqsubseteq \sigma \otimes_T \tau
\]
Pure Selection: Artifactual Type

The beer spoiled.

(89)

\[
\text{liquid} \otimes_T \text{drink} : e_A
\]

\[
\lambda x : e_A[\text{spoil}(x)]
\]

\[
\text{liquid} \otimes_T \text{drink} \sqsubseteq \sigma \otimes_T \tau
\]
Function Application with Complex Types

Function Application: If $\alpha$ is of type $e_C$, and $\beta$ is of type $e_C \rightarrow t$, then $\beta(\alpha)$ is of type $t$.

A complex type tree:
Pure Selection: Complex Type

John read the book.

(90)
Pure Selection: Complex Type

John read the book.

(91)

\[
\begin{aligned}
&\text{VP} \\
&\quad \vdash p \cdot i \\
&\quad \vdash \text{NP: phys } \cdot \text{info} \\
&\quad \vdash \lambda y: p \cdot i \lambda x: e_N[\text{read}(x,y)]\text{the} \\
&\quad \vdash \text{N} \\
&\vdash \text{book}
\end{aligned}
\]
Accommodation with Natural Types

Accommodation: If $\alpha$ is of type $\sigma$, and $\beta$ is of type $\tau \to t$, then, if $\sigma \sqcap \tau \neq \bot$, then $Acc(\beta, \alpha)$ is of type $\sigma \sqcap \tau \to t$. 
Type Accommodation: Natural Types

Mary wiped her hands.

(92) VPHHHHH

V -surface NP:phys
wipe

Det
her

N
body_part
hands
Type Accommodation: Natural Types

Mary wiped her hands.

(93)

\[
\begin{array}{c}
\text{VP} \\
\text{wipe} \\
\text{[surface]} \\
\text{NP:phys} \\
\text{Det} \\
\text{her} \\
\text{N} \\
\text{body \_ part} \\
\text{hands}
\end{array}
\]
Type Accommodation: Natural Types

Mary wiped her hands.

(94)
Type Coercion: Natural to Artifactual Introduction

The water spoiled.

(95)

\[
S \rightarrow_{\sigma \otimes T \tau} \text{NP} \rightarrow_{\lambda x : e_A[spoil(x)]} \text{VP} \rightarrow_{\text{the water}} \text{spoil}
\]

\[
\text{liquid} : e_N
\]

121
Type Coercion: Natural to Artifactual Introduction

The water spoiled.

\[(96)\]

\[
\begin{array}{c}
\text{NP} \\
\text{liquid} : e_N \\
\text{the water} \to \text{VP} \\
\text{spoiled} \\
\lambda x : e_A[\text{spoil}(x)]
\end{array}
\]
Type Coercion: Artifactual Accommodation

The water spoiled.

(97)

\[
\lambda x : e_A[spoil(x)]
\]
John read the rumor.

(98)

\[
\lambda y : p \cdot i \lambda x : e_N[\text{\textit{read}}(x,y)] \rightarrow \text{NP:info}
\]

\[
\text{VP} \rightarrow \text{V \textit{phys} \cdot \textit{info} \rightarrow NP:info}
\]

\[
\text{read} \rightarrow \text{Det the} \rightarrow \text{N rumor}
\]
Type Coercion: Natural to Complex Introduction

John read the rumor.

\( \lambda y: p \cdot i \lambda x: e_N[read(x,y)] \)
Type Coercion: Event Introduction

Mary enjoyed her coffee.

(100)

Type Coercion: Event Introduction

Mary enjoyed her coffee.

(100)

Type Coercion: Event Introduction

Mary enjoyed her coffee.
Type Coercion: Event Introduction

Mary enjoyed her coffee.

(101)

```
VP
  | [event]  λx.Event(x, NP)
  V
enjoy NP:liquid ⊗_T drink
  | [portion]
  Det her N [mass] coffee
```
Type Coercion: Qualia Exploitation

Mary enjoyed her coffee.

(102)
Type Coercion: Qualia Exploitation

Mary enjoyed her coffee.

(103)

\[ \lambda x. \text{drink}(x, \text{NP}) \vDash \text{NP: liquid} \otimes_T \text{drink} \]
Type Coercion: Complex Exploitation

The police burned the book.

(104)

\[
\lambda y : \text{phys} \lambda x : e_N [\text{burn}(x, y)] \quad \text{Burn}
\]

\[
\text{Det} \quad \text{the} \quad \text{N} \quad \text{book}
\]
Type Coercion: Complex Exploitation

The police burned the book.

(105)
Type Coercion: Complex Exploitation

Mary believes the book.

\[ \lambda y : \text{phys} \lambda x : e_N \{ \text{believe}(x,y) \} \]

Diagram:

```
VP  info  NP:phys • info
    |                    |
     V                     NP
       |                 |                     no
     believe  Det  N
       |  the  | book
```

(106)
Type Coercion: Complex Exploitation

Mary believes the book.

(107)

\[ \lambda y: \text{phys} \lambda x: e_N \{ \text{believe}(x,y) \} \]

\[ \text{VP} \]

\[ \text{believe} \quad \text{Det} \quad \text{NP:phys} \bullet \text{info} \]

\[ \text{the} \quad \text{book} \]
Types and Composition of Local Contexts

Compositionality mediated through richer selectional mechanisms:

<table>
<thead>
<tr>
<th>COMPOSITION</th>
<th>VERB TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>die($x$)</td>
</tr>
<tr>
<td>Accommodation</td>
<td>wipe($x$,hand)</td>
</tr>
<tr>
<td>Coercion</td>
<td>enjoy($\text{rock}$)</td>
</tr>
<tr>
<td></td>
<td>fix($x,y$)</td>
</tr>
<tr>
<td></td>
<td>spill($\text{beer}$)</td>
</tr>
<tr>
<td></td>
<td>burn($x$,book)</td>
</tr>
<tr>
<td></td>
<td>spoil($\text{water}$)</td>
</tr>
<tr>
<td></td>
<td>read($x$,joke)</td>
</tr>
</tbody>
</table>
That’s all well and good, but...
That’s all well and good, but...

What do we actually see in the corpus?