Lexicon in Linguistic Theory

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Lecture 6: General Architecture of the Lexicon: Syntactic and Semantic Type Hierarchies
Lecture 6: July 11

General Architecture of the Lexicon: Syntactic and Semantic Type Hierarchies

- Lexical Architecture
- Syntactic Type Hierarchy
- Semantic Type Hierarchy
- Lexical Semantic Relations
- Morphology and Word Structure
What is an Architecture for the Lexicon?

Join Relation

- LEXICAL ARCHITECTURE provides us with the **content**, **functionality**, and **organization** of lexical information;
- One of the major organizing principles in the lexicon is the notion of a **TYPE HIERARCHY**;
- TYPES (classes) in our domain are ordered by a subtyping relation, $\subseteq$, defined as a partial order on the set of types, $\mathcal{T}$.

\[ A \]
\[ B \quad C \quad D \]

- $A$ has subtypes $B$, $C$, and $D$, where holds between each subtype and its parent: $B \subseteq A$, $C \subseteq A$, and $D \subseteq A$.
- $A$ can be defined configurationally by its relations to its daughters: that is, it is the **least upper bound** for $B$, $C$, and $D$. Using the operation, $\sqcup$, called join, we see that $A = B \sqcup C \sqcup D$. 
Inheritance Hierarchies

Meet Relation

- If we can intersect the properties of different types, then we have an operation called *meet*, \( \sqcap \), which is formally the greatest lower bound of two types.
- In the tree below, \( E \) is the meet of \( C \) and \( D \).

\[
\begin{aligned}
& \text{A} \\
& \quad \left\{ \begin{array}{c}
& \text{B} \\
& \quad \text{C} \\
& \quad \quad \text{D} \\
& \quad \quad \quad \text{E}
\end{array} \right.
\end{aligned}
\]

- Category \( E \) inherits all the properties from both \( C \) and \( D \) above it.
- Such **MULTIPLE INHERITANCE** structures, where a type is defined by referring to two parent types, will be needed for several type hierarchies in the lexicon.
Syntactic Type Hierarchy

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Exploiting Type Inheritance

Different syntactic categories can share the same syntactic valence:

- verbs *die* and *arrive* and the prepositions *about* and *into* must be combined with one NP argument (as subject and prepositional object, respectively);
- the nouns *mother* and *edge* and the adjectives *capable* and *skilled* take a PP argument.

(3) a. *[The plane]* *arrived*: [NP]_1
   b. *into* *[the house]*: [NP]_1

(4) a. *edge* *[of the table]*: [PP]_1
   b. *skilled* *[at chess]*: [PP]_1
Syntactic Features are Insufficient to Determine Selection

- While the expressions in (5) have the categorial and valence features required by *build* ([NP, NP]₂) and *mother* ([PP]₁), they are unacceptable because the nominal arguments have the wrong semantic features.

(5)  
\begin{align*}
\text{a. } & \text{ *[An idea]}_{NP} \text{ builds [the sand]}_{NP}. \\
\text{b. } & \text{ *mother [of the knife]}_{PP}
\end{align*}

\begin{align*}
\textbf{AS} = \begin{bmatrix}
\text{build} \\
\text{ARG}_1 = \begin{bmatrix}
\text{ARG}_2 = \begin{bmatrix}
\text{X} = \begin{bmatrix}
\text{CAT} = \text{DP} \\
\text{SEM TYPE} = \text{animate}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{align*}

(6)

- Both syntactic and semantic selectional restrictions are needed to specify grammatical behavior.
- In (6), both syntactic type and selectional semantic features are encoded as features of the arguments in the argument structure for *build*.
Semantic Selectional Restrictions

- For relational nouns, such as *mother*, and for nouns generally, syntactic valence and selectional restrictions are also encoded in the lexical representation in the argument structure;
  - SORTAL_NOUN(\text{arg}_{\text{ref}})
  - RELATIONAL_NOUN(\text{arg}_{\text{ref}},\text{arg}_{\text{rel}})

\begin{align*}
(7) & \quad \text{mother} \\
& \quad \text{CAT} = \text{count-N} \\
& \quad \text{SEM} = \left[ \text{ARG}_{\text{ref}} = \left[ \text{SEM TYPE} = \text{animate} \right] \right] \\
& \quad \text{AS} = \left[ \text{ARG}_1 = \left[ \text{y} = \left[ \text{CAT} = \text{PP(of+NP/DP)} \right] \right] \right]
\end{align*}

\begin{align*}
(8) & \quad \text{boy} \\
& \quad \text{CAT} = \text{count-N} \\
& \quad \text{SEM} = \left[ \text{ARG}_{\text{ref}} = \left[ \text{SEM TYPE} = \text{human} \right] \right]
\end{align*}
In a **simple taxonomic hierarchy**, each subtype inherits information from one supertype.

*Building* is the **hypernym** of *warehouse*, *bungalow*, and *fortress*, which are the **hyponyms** of *building*.

A *warehouse*, a *bungalow* or a *fortress* is-a kind of *building*.

**BUILDING ⊆ INANIMATE ⊓ COUNT ⊓ ARTIFACT**

(9)

```
    BUILDING
    /\      /\      /\  
warehouse bungalow fortress
```

**WAREHOUSE ⊆ BUILDING**

**BUNGALOW ⊆ BUILDING**

**FORTRESS ⊆ BUILDING**
We introduce a new type, `PURPOSE`, with its own subtypes, `STORE`, `DWELL`, and `DEFEND`.

The subtype associated with the word `warehouse` is then formed by inheriting information from both `BUILDING` and the purpose type `STORE`, as are the other subtypes with their respective purpose types.

```
warehouse = BUILDING ⊓ STORE
bungalow = BUILDING ⊓ DWELL
fortress = BUILDING ⊓ DEFEND
```
Semantic Type Hierarchies

- **Ontological Types**
  - Top
    - Entity
      - Physical
      - Abstract
    - Property
      - Intrinsic
      - Extrinsic
    - Event
      - Dynamic
      - Static

- **Individuation** - a *transcategorial lexical-semantic feature*
  - Individuation
    - Bounded
      - B_SET
      - Atomic
    - Unbounded
      - U_SET
      - Homogeneous
Semantic Type Hierarchy

Semantic Type Hierarchy

Ontological

Entity

Animate, Inanimate

Property

Static, Dynamic

Event

Bound, Unbound

Individuation

B_set, Aтомic

U_set, Homogeneous

Committee, Girl, Livestock, Dancer, Stack, Table, Rice, Water, Hungry, Broken, Smart, Own, Build, Die, Run, Jump

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Qualia-defined Types

- Lexical type *warehouse* inherits a **telic** value from the event *store*.
- Lexical type *building* inherits its **agentive** role from the event *create*.
Ontological Types with Qualia and Individuation

For the purpose of visualization we interpret "AGENTIVE" and "TELIC" roles as transcategorial features, allowing us to examine the global structure of the type system.
Navigating the Type System

- \( girl = \text{ANIMATE} \cap \text{NATURAL}; \)
- \( water = \text{INANIMATE} \cap \text{NATURAL}; \)
- \( committee = \text{ANIMATE} \cap \text{FUNCTIONAL}; \)
- \( table = \text{INANIMATE} \cap \text{FUNCTIONAL}. \)

- \( committee = \text{ANIMATE} \cap \text{B\_SET}; \)
- \( table = \text{INANIMATE} \cap \text{ATOMIC}. \)
- \( rice = \text{INANIMATE} \cap \text{U\_SET}; \)
- \( water = \text{INANIMATE} \cap \text{HOMOGENEOUS}. \)
Navigating the Type System

(10) a. **Natural properties:**
    
    *hungry, smart* = PROPERTY \(\sqcap\) NATURAL;

    b. **Functional properties:**
    
    *broken* = PROPERTY \(\sqcap\) FUNCTIONAL.

(11) a. **Stage-level properties:**
    
    *hungry, broken* = PROPERTY \(\sqcap\) ATOMIC;

    b. **Individual-level properties:**
    
    *smart* = PROPERTY \(\sqcap\) HOMOGENEOUS.

(12) a. **Natural events:**
    
    *own, die, run, jump* = EVENT \(\sqcap\) NATURAL;

    b. **Functional events:**
    
    *build* = EVENT \(\sqcap\) FUNCTIONAL.
Semantic subtyping of ENTITY

- ENTITY
  - PHYSICAL
    - ANIMATE
    - INANIMATE
  - PROPOSITION
  - TEMPORAL
    - TIME
    - ORDER
  - SPATIAL
    - DIRECTION
    - LOCATION
  - QUANTITY
    - NUMBER
    - DEGREE
  - MANNER
    - happily
  - LOGICAL
    - bigger than

- Semantic subtyping includes:
  - Physical: animate, inanimate
  - Propositional
  - Temporal: time, order
  - Spatial: direction, location
  - Quantitative: number, degree
  - Manner: happily
  - Logical: bigger than

- Examples:
  - Physical: animate - animal, inanimate - table
  - Propositional: fact, information, truth, rumor
  - Temporal: time - tonight, before/after, order - towards, location - here
  - Quantitative: number - three, degree - severe(ly)
  - Manner: happily
  - Logical: bigger than
Defining Entity and Event Classes

Different classes of entities (dog, water, rice, etc.) can be distinguished by establishing different meet relations of ENTITY (or subtypes PHYSICAL and ABSTRACT) with different values within INDIVIDUATION.

(13) **Entity classes:**
   a. Individual: ENTITY □ ATOMIC
   b. Group: ENTITY □ B_SET
   c. Aggregate: ENTITY □ U_SET
   d. Substance: ENTITY □ HOMOGENEOUS

Vendler’s event classes can be defined when the subtypes of EVENT (STATIC and PROCESS) combine with different meet relations within INDIVIDUATION.

(14) **Event classes:**
   a. State: STATIC □ HOMOGENEOUS
   b. Accomplishment: DYNAMIC □ B_SET
   c. Achievement: DYNAMIC □ ATOMIC
   d. Activity: DYNAMIC □ HOMOGENEOUS
Complex Types and Logical Polysemy

- The lunch<sub>EVENT</sub> lasted two hours. But it<sub>ENTITY</sub> was delicious.
- The book<sub>ENTITY</sub> cost $25.00. And it<sub>PROPOSITION</sub> is confusing!
Hyperonymy and Hyponymy

- Sense relations between a general term (hypernym, \( A \)) and a more specific term (hyponym, \( B \)).
- \( B \subseteq A \): ‘\( B \) is a kind of \( A \)’
- If \( C \subseteq B \) and \( B \subseteq A \), then \( C \subseteq A \).
- ‘A rose is a flower is a plant is a physobj is an entity.’
Troponymy
Hyponymy relation between verb types

A verb’s type can be specialized by specifying:

- a distinct *means* of performing an activity:
  - *means subtyping*, $\subseteq_{me}$

- the different *manners* in which an activity can be performed:
  - *manner subtyping* relation, $\subseteq_{ma}$
Means Troponymy

- Mary **cut** the \{wood/ tree/ bread\}.
- Mary **sawed** the wood (=‘cut with a saw’).
  - SAW $\subseteq$ INSTRUMENT
- Mary **axed** the tree (=‘cut with an ax’).
  - AX $\subseteq$ INSTRUMENT
- Mary **sliced** the bread (=‘cut with a knife’).
Manner Troponymy

- Category $B$ is a “manner subtype” of a category $A$, $B \subseteq_{ma} A$, if and only if $B$ specifies a particular manner in which to perform $A$.
- Motion verbs *stroll*, *stagger*, *stride*, and *saunter* are considered manner subtypes of *walk*, denoting a certain manner of walking.

```
WALK
    /\    /
  stroll  stagger  stride
    \    /
      saunter
```
Mixed Troponym Hierarchies

- **TALK** $\sqsubseteq_{me}$ COMMUNICATE
- **WRITE** $\sqsubseteq_{me}$ COMMUNICATE
- **GESTICULATE** $\sqsubseteq_{me}$ COMMUNICATE

Diagram:

```
COMMUNICATE
  /   \
/talk     write     gesticulate
    /   \\
   babble  mumble slur bark whisper  sign scribble type  handwrite wink clap nod shrug
```

- **WHISPER** $\sqsubseteq_{ma}$ TALK;
- **SCRIBBLE** $\sqsubseteq_{ma}$ WRITE;
- **NOD** $\sqsubseteq_{ma}$ GESTICULATE
Incompatible Types

Incompatibility: Subtypes of the same supertype have no members in common.

- When it is binary, then we refer to it as a contradiction.
  - This number is even. \( \equiv \) This number is not odd.
  - This number is not even. \( \equiv \) This number is odd.

- When it is multi-valued, then we refer to it as a contrary nominal scale.
  - This student is a senior. \( \equiv \) This student is not a freshman, sophomore, or junior.
  - This cup is not plastic. \( \neq \) This cup is ceramic.

- When it is multi-valued and partially ordered, then we refer to it as a contrary ordinal scalar.
  - This shirt is wet. \( \equiv \) This shirt is not dry.
  - This shirt is not wet. \( \neq \) This shirt is dry.
Scalar Attribution and Types

The properties of the scale lexicalized by the predicate to determine its aspect, e.g., in deadjectival gradual achievement Vs (Hay et al. 1999, Kennedy and Levin 2008).

Scalar classes of adjectives:

a. Open scales
   *totally/*somewhat \{wide/ long/ deep\}

b. Totally closed scales
   totally/somewhat \{empty/ open/ visible\}

c. Lower closed scales
   ?totally/somewhat \{wet/ dirty/ sick\}

d. Upper closed scales
   totally/*somewhat \{straight/ clean/ flat\}
Scalar Properties of Events

- Multi-valued scales can yield durative atelic (*weakly telic*) predicates denoting a non-maximal degree of change:
  a. John is widening the gap. ⇒ John has widened the gap somewhat.
  b. John is emptying the tank. ⇒ John has emptied the tank somewhat.
  c. Jaco is dirtying the floor. ⇒ Jaco has dirtied the floor somewhat.
  d. John is flattening the wire. ⇒ John has flattened the wire somewhat.

- Predicates based on a partially or totally closed scale can have a telic interpretation conveying that one of its bounds has been reached.
  a. #John widened the gap completely and now the gap is wide.
    [with respect to a previously planned width]
    open scale, a contextually-relevant scale limit provided for telic reading
  b. John emptied the tank completely and now the tank is empty.
    totally closed scale, upper degree is involved in telic reading
  c. Jaco dirtied the floor (*completely) and now the floor if dirty.
    lower closed scale, lower degree is involved in telic reading
  d. John flattened the wire completely and now the wire is flat.
    upper closed scale, upper degree is involved in telic reading

- 2-valued scales → [-durative] [+telic] predicates.
Scalar Type Structure
How scalar concepts fit within a semantic type hierarchy

- Rather than assigning scalar classes to individual adjectives, let us categorize the *dimension* itself as being associated with a specific scalar structure.
- An attribute refers to a *conceptual type* in the PROPERTY subhierarchy, while the values of this attribute are *lexical types*;
- The conceptual type for an attribute may also have a lexicalization (e.g., *height*, *cost*);
- The values, $v_i$, for any scalar attribute, $A$, are structured by an ordering relation, $<$, indicating the position of $v_i$ on the scale denoted by the attribute.
Scalar Type Structure

- Some scales have a minimum (MIN) or maximum (MAX) value, or both.
- The MIN value is the lowest ordered value on the scale, while the MAX is the highest ordered value, according to that scale.
  - empty is the lowest value on a scale indicating the quantity of content in a container.
- Some scales have a contextualized (or relative) MIN or MAX value (such as short/tall), but not absolute values, i.e., MIN*, and MAX*;
  - For the HEIGHT, we say that short < medium, and medium < tall.
  - By a rule of transitive ordering, we can infer that short < tall.
- For either a MIN*, such as short, or a MAX*, such as tall, it is possible to find a value that is smaller or larger (respectively).
  - We can think of such open ends as “semi-closed”;
- In addition to the four classes mentioned above, we add two more, LOWER-CLOSED/UPPER-SEMI-CLOSED SCALE:
  - LOWER-CLOSED/UPPER-SEMI-CLOSED SCALE wet/dry;
  - LOWER-SEMI-CLOSED/UPPER-CLOSED SCALE open/closed.
Six Scalar Values for Dimensional Types (1-3)

- SEMI-CLOSED SCALE: *short*/ *tall*
  
  ATTRIBUTE
  
  \[\ldots < \text{MIN}^* < \ldots < \text{MAX}^* < \ldots\]\n
- CLOSED SCALE: *empty*/ *full*
  
  ATTRIBUTE
  
  \[\text{MIN} < \ldots < \text{MAX} \]

- LOWER-CLOSED SCALE: *stained* (MIN)
  
  ATTRIBUTE
  
  \[\text{MIN} < \ldots < \ldots \]
Six Scalar Values for Dimensional Types (4-6)

- **UPPER-CLOSED SCALE**: *flat* (MAX)

  ![Diagram for UPPER-CLOSED SCALE]

- **LOWER-CLOSED/UPPER-SEMI-CLOSED**: *wet*/*dry*

  ![Diagram for LOWER-CLOSED/UPPER-SEMI-CLOSED]

- **LOWER-SEMI-CLOSED/UPPER-CLOSED**: *open*/*closed*

  ![Diagram for LOWER-SEMI-CLOSED/UPPER-CLOSED]
Meronymy and Holonymy

The Semantics of Part Structures

- We introduce a **PART-OF** relation, $\subseteq_c$ (a kind of **CONSTITUTIVE** relation), between types $A$ and $B$.
- A word $w_1$ is said to be a **meronym** of a word $w_2$, if and only if $w_1$'s type, $A$, forms a part-of $w_2$'s type, $B$: i.e., $A \subseteq_c B$.
- Conversely, if this relation holds, then $w_2$ is the **holonym** of $w_1$.

<table>
<thead>
<tr>
<th>PART-WHOLE RELATION</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. COMPONENT-OBJECT</td>
<td>handle-door, finger-hand</td>
</tr>
<tr>
<td>b. MEMBER-COLLECTION</td>
<td>tree-forest, card-deck</td>
</tr>
<tr>
<td>c. MATERIAL-OBJECT</td>
<td>gold-ring, water-lemonade</td>
</tr>
<tr>
<td>d. UNIT-MASS</td>
<td>slice-pie, grain-rice</td>
</tr>
<tr>
<td>e. FEATURE-ACTIVITY</td>
<td>pay-shop, swallow-drink</td>
</tr>
<tr>
<td>f. PLACE-AREA</td>
<td>Madrid-Spain, oasis-desert</td>
</tr>
</tbody>
</table>

**Table:** Types of part-of Relations
If $\text{TYPE}(w)$ denotes the semantic type of the word $w$, then $\text{TYPE}(\text{handle}) \subseteq \text{TYPE}(\text{door})$, and $\text{TYPE}(\text{finger}) \subseteq \text{TYPE}(\text{hand})$.

Notice that the COMPONENT-OBJECT relation exhibits transitivity: i.e., if $A \subseteq B$ and $B \subseteq C$, then $A \subseteq C$.

(15) a. $\text{TYPE}(\text{finger}) \subseteq \text{TYPE}(\text{hand})$: finger is a meronym of hand;
    b. $\text{TYPE}(\text{hand}) \subseteq \text{TYPE}(\text{body})$: hand is a meronym of body;
    c. $\text{TYPE}(\text{finger}) \subseteq \text{TYPE}(\text{body})$: finger is a meronym of body.
Member-Collection

- The semantic type of a COLLECTION is SET (B_SET or U_SET): hence it will inherit the ONTOLOGICAL type from that of its members.

- That is, sets and collections of things inherit the type associated with the collected objects (e.g., collections of humans can be treated as human, etc.).

  - Since card is an ATOMIC individual, lexically typed as INANIMATE ⊓ AGENTIVE, the COLLECTION term, deck, will be a B_SET, also typed as INANIMATE ⊓ AGENTIVE

  - Any type, TYPE, can, in principle, be a MEMBER of a COLLECTION, since COLLECTION acts as a function to make a set of those elements: i.e., COLLECTION: TYPE → SET.
Material-Object

- **PART-OF** type corresponds to the “made-of” relation.
- This is effectively the material **CONSTITUTIVE** qualia role for an object
  - the *ring* is made of *gold*,
  - the *lemonade* is made of *water, lemon, and sugar*;
- The noun *ring* is lexically typed as a physical artifact:  **INANIMATE □ ARTIFICIAL □ TELIC □ ATOMIC**;
- the noun *gold* is typed as a substance, i.e., **INANIMATE □ NATURAL □ HOMOGENEOUS**.
- This is expressed as the following **PART-OF** relation:  \( \text{TYPE}(gold) \sqsubseteq_c \text{TYPE}(ring) \).
Patterns of Type-Driven Inference

- This tree is part of the forest. MEMBER-COLLECTION;
- This forest is part of the city. PLACE-AREA;
- ! This tree is part of the city. *MEMBER-AREA.

- A roof is part of a house. COMPONENT-OBJECT;
- A house is part of a subdivision. MEMBER-COLLECTION;
- ! A roof is part of a subdivision. *COMPONENT-COLLECTION.