Semantic Theory

Lexical Semantics IV

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Davidsonian event semantics

(1) The gardener killed the baron at midnight in the park
⇒ $kill_4(g, b, m, p)$
(2) The gardener killed the baron at midnight
⇒ $kill_3(g, b, m)$
(3) The gardener killed the baron in the park
⇒ $kill_2(g, b, p)$
(4) The gardener killed the baron
⇒ $kill_1(g, b)$

Davidson's solution:

$$\exists e[\ kill(e,g,b) \wedge time(e, m) \wedge location(e, p)\ ]$$

A Related Problem?

John broke the window with a rock
A rock broke the window
The window broke

$break_3(j, w, r) \models break_2(r, w) \models break_1(w)$

John flew Bill with the plane to Frankfurt
John flew by plane to Frankfurt
The plane flew to Frankfurt

$fly_4(x,y,z,u) \models fly_3(z,y,u) \models fly_2(y,u)$

A Related Problem?

- The number of overtly realized arguments can vary, but there is a maximum verb-specific set of arguments.
- The arguments under consideration are (typically) realized as complements, not as free adjuncts.
- One syntactic complement type can bind different „argument positions" – one argument position can be realized through different complement types.
- More precisely: The same argument grid of the verb can be realized through different syntactic patterns.
- The relation between predicate-argument structure and possible syntactic realizations is verb-specific.

Syntactic alternations are verb-specific

The options for realizing

John broke the window
The window broke

- But:

Margaret cut the bread
**The bread cut*

The butcher cuts the meat
The meat cuts easily

- But:

Joan knew the answer
**The answer knows easily*

B. Levin's verb classes

	middle alternation
Margaret cut the bread	The bread cuts easily
Janet broke the vase	Crystal vases break easily
Terry touched the cat	*Cats touch easily
Carla hit the door	*Doors hit easily

conative alternation	body-part possessor ascension alternation
Margaret cut at the bread	Margaret cut Bill on the arm
*Janet broke at the vase	*Janet broke Bill on the finger
*Terry touched at the cat	Terry touched Bill on the shoulder
Carla hit at the door	Carla hit Bill on the back

- Different verbs are subject to different alternation patterns.
- Verbs sharing their alternation patterns form semantic classes.
  - *Cut* verbs: *cut, saw, scrape, scratch, ...*
  - *Break* verbs: *break, split, tear, ...*

Modeling syntactic alternations: First attempt

- Express the semantic relation between different syntactic realizations through
  - canonical argument ordering
  - existential binding of unfilled argument positions

John broke the window with a rock
⇒ break (j, w, r)

A rock broke the window
⇒ ∃x.break(x, w, r)

The window broke
⇒ ∃x∃y.break(x, w, y)

Semantic roles

- The key for modeling this kind of phenomena is the notion of a semantic role (introduced by C. Fillmore in the late sixties).
- Terminology: Fillmore originally spoke about "deep cases" (in contrast to "surface cases" of syntax). In between, linguists talk about "thematic roles", computational linguists mostly of "semantic roles".
- Example:
  - *[John]$_{ag}$ broke [the window]$_{pat}$ [with a rock]$_{inst}$*
  - *[A rock]$_{inst}$ broke [the window]$_{pat}$*
  - *[The window]$_{pat}$ broke*

What are thematic roles?

- According to C. Fillmore, understanding a verb (or any other predicate) means to know the situation type or conceptual schema associated with or evoked by it.
- Part of the situation type or conceptual schema are typical participants, persons or objects that play a specific role in the event or action expressed by the predicate.
- In standard logical terms, these participants are just the logical arguments of the predicate.
- Thematic roles are indices expressing the specific contribution of the participants to the situation, or their semantic status of the arguments with respect to the described conceptual schema.

Roles and Predicate Logic

- In standard FOL, the relation of the members of the argument set to the predicate in a predicate-argument structure can be expressed by their (canonical) order: First argument position is filled by the agent, second by the patient, etc.

  break (j, w, r)

  ∃x.break(x, w, r)

  ∃x∃y.break(x, w, y)
- We can use role indices to explicitly mark the status of the argument positions:

  break (j_{ag}, w_{pat}, r_{inst})
- Equivalently, we can encode arguments as feature structures/ records:

  break ([ag: j; pat: w; inst: r])

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Roles and Predicate Logic (2)

- Alternative option: Treat complements analogously to adjuncts in Davidsonian Semantics.
- Thematic roles are two-place relations between the event denoted by the verb, and an argument role filler.
- The event verb itself is just a one-place predicate taking an event as argument.
- Examples:

  John broke the window with a rock

  ⇒ ∃e [break(e) ∧ ag(e,j) ∧ pat(e,w) ∧ inst (e,r)]

  The gardener killed the baron at midnight in the park

  ⇒ ∃e [kill(e) ∧ ag(e,g) ∧ pat(e,b) ∧ time(e,m) ∧ location(e,p)]
- This analysis is called „Neo-Davidsonian“ or „radical Davidsonian“ event semantics.

What are roles good for?

- Thematic roles capture syntactic verb alternations: equivalent uses with different realization of "the same" semantic argument positions.

(1) *John broke the window with a rock*
⇒ ∃e [break(e) ∧ ag(e,j) ∧ pat(e,w) ∧ inst (e,r)]
(2) *A rock broke the window*
⇒ ∃e [break(e) ∧ pat(e,w) ∧ inst (e,r)]
(3) *The window broke*
⇒ ∃e [break(e) ∧ pat(e,w)]

(1) ⊨ (2) ⊨ (3)

- Roles + Neo-Davidsonian representation enable the partitioning of semantic information into minimal pieces: One-place predicates and two-place relations.

Selectional preferences

- Thematic roles enable a more appropriate description of selectional preferences/ constraints:
  - The subject of *break* is either animate or solid object or breakable object
  - The agent of *break* is animate
  - Generalization: Agent is animate

Modeling cross-lexical relations

- From the beginning, the concept of a thematic role was intended for a wider, cross-lexical application.
- Role semantics does not only relate different uses of the same predicate, but relates different predicates, which describe the same situation type.

John likes Mary
Mary pleases John

Mary gave Peter the book
Peter received the book from Mary

The gardener killed the baron
The baron died

Modeling cross-lexical relations

- Thematic roles capture equivalences/ entailment relations between different predicates with different syntactic realization patterns:

(1) *Mary gave Peter the book*
⇒ ∃e [give(e) ∧ ag(e,m) ∧ pat(e,b) ∧ rec (e,p)]

(2) *Peter received the book from Mary*
⇒ ∃e [receive(e) ∧ ag(e,m) ∧ pat(e,b) ∧ rec (e,p)]

- ∀e (give(e) ↔ receive(e)) ⊨ (1) ↔ (2)

Roles in semantic construction

- How do we get from a surface sentence to its role-semantic representation?
  - *give* ⇒ λyλzλxλe[give(e) ∧ ag(e,x) ∧ pat(e,y) ∧ rec (e,z)]
  - *receive* ⇒ λzλxλyλe[receive(e) ∧ ag(e,x) ∧ pat(e,y) ∧ rec (e,z)]
- Not a good idea. We should exploit role information for composition.
- Two tasks:
- Role Linking: How can syntactic relations between verb and arguments be mapped to thematic roles?
- Semantic Construction: How can we integrate role information in type-logical semantics?

Role Linking

- Part of the linking process is regular. Example:
  - An overt agent always becomes subject.
  - If there is no overt agent, the instrument becomes subject.
  - If there is neither agent or instrument, the theme becomes subject.
- Linguistic grammar theories try to describe role linking as a systematic process, which is part of the grammar, working, e.g., with "obliqueness hierarchies". Problem: Linking has really unsystematic and idiosyncratic aspects.
- In knowledge-based computational linguistics, linking information is typically provided in the lexicon, stated explicitly for each syntactic.

  break$_1$: *Subj* → *Agent, DObj* → *Patient, PObj* → *Instrument*
  break$_2$: *Subj* → *Instrument, DObj* → *Patient*
  break$_3$: *Subj* → *Patient*
- Semantic role labeling as an important task in statistical computational semantics.

Semantic composition:

Use role information to drive semantic composition:

- Index λ-variables with role labels.
- Index complements with role labels.
- Impose identity of role indices as an additional condition on conversion.
- Then do away with the ordering of the variables in the λ-prefix: You don't need it anymore.

Order-free λ-Abstraction

Order-free abstraction:

- *give* ⇒ $\lambda\{x_{ag}, y_{pat}, z_{rec}, e_{ref}\}$. give(e) ∧ ag(e,x) ∧ pat(e,y) ∧ rec (e,z)
- *receive* ⇒ $\lambda\{x_{ag}, y_{pat}, z_{rec}, e_{ref}\}$. receive(e) ∧ ag(e,x) ∧ pat(e,y) ∧ rec (e,z)

Application: give'(the_book'$_{pat}$)(mary'$_{rec}$)(john'$_{ag}$)

β-reduction: $[\lambda X.\alpha](\beta_r) \Leftrightarrow \lambda(X-\{x_r\}).\alpha^{\beta/x}$, if $x_r \in X$.

Additional clause: $\lambda\varnothing.\alpha \Leftrightarrow \alpha$

Note: The result of the application is independent of the order in which the arguments occur.

Generalization: Simultaneous application and reduction:

$[\lambda X.\alpha](\{\beta_{i1}, ..., \beta_{in}\}) \Leftrightarrow \lambda(X-\{x_{i1}, ..., x_{in}\}).\alpha^{\beta i1/xi1 \ ... \ \beta in/xin}$, if $\{x_{i1}, ..., x_{in}\} \subseteq X$.

What is the appropriate role inventory?

- According to Fillmore (1968), thematic roles form a small, closed, and universally applicable inventory conceptual argument types.
- A typical role inventory might consist of the roles: Agent, Theme (Patient, Object),Recipient, Instrument, Source, Goal, Beneficiary, Experiencer.
- But: A closed inventory of 8 or 12 or even 20 roles is not sufficient to describe the wealth of predicate-argument relations.
  - *Lufthansa is replacing its 737s with Airbus 320*
  - *John sold the car to Bill for 3,000€*
  - *Bill bought the car from John for 3,000€*

Possible Answers

- Use a separate role inventory for every lemma (PropBank).
- Frame-based role inventories (C. Fillmore, FrameNet)

Frame Semantics

- Structured schemata representing complex prototypical situations, events, and actions are the basic inventory for the conceptual modelling of the world. These are called frames.
- Frames are „evoked“ by NL expressions,typically content words (also called frame-evoking elements (FEEs) or target words).
- Thematic roles are neither universal nor lemma-specific: Role specifications have local validity for the target words of a frame (therefore also called frame elements/ FEs).

FrameNet and PropBank

[$_{\text{Agent}}$ *Lufthansa*] *is replacing* $_{\text{Frame: REPLACING}}$ [$_{\text{Old}}$ *its 737s*] [$_{\text{New}}$ *with Airbus A320s*]

[$_{\text{Agent}}$ *Lufthansa*] *is substituting* $_{\text{Frame: REPLACING}}$ [$_{\text{New}}$ *Airbus A320s*] [$_{\text{Old}}$ *for its 737s*]

$$\begin{bmatrix} Frame & REPLACING \\ Agent & Lufthansa \\ Old & its737s \\ New & AirbusA320s \end{bmatrix}$$

An Example

- Airbus sells five A380 planes to China Southern for 220 million Euro
- China Southern buys five A380 planes from Airbus for 220 million Euro
- Airbus arranged with China Southern for the sale of five A380 planes at a price of 220 million Euro
- Five A380 planes will go for 220 million Euro to China Southern

An Example

Common frame-semantic Analysis:

Frame: COMMERCIAL_TRANSACTION
SELLER: Airbus
BUYER: China Southern
GOODS: five A380 planes
PRICE: 220 million Euro

Event-Semantic representation

$\exists e$ [COMMERCIAL_TRANSACTION(e) $\wedge$
seller(e, Airbus) $\wedge$ buyer(e,C.S.) $\wedge$
goods (e, 5_A380) $\wedge$ price (e,220m€)]

The Berkeley FrameNet Database

The FrameNet database consists of:

- A data-base of frames with
  - Descriptions of frames with inventory of Roles/Frame elements and associated lemmas
  - Frame-to-Frame Relations
- A lexicon with
  - Frame information
  - Grammatical realisation options (underspecified role linking information)
  - Annotations of example sentences (from BNC) for all usage variants of words

Example Frames

- Frame: REQUEST
  Frame Elements: SPEAKER, ADDRESSEE, MESSAGE, MEDIUM, ...
  Lexical Units: *appeal.n, ask.v, beg.v, beseech.v, call.v, command.n, command.v, demand.n, demand.v, entreat.v, entreaty.n, implore.v, invite.v, order.n, order.v, petition.n, plea.n, plead.v, request.n, request.v, suggestion.n, summon.v, tell.v, urge.v*
- Frame: COMMERCE
  Frame Elements: BUYER, SELLER, GOODS, ...
  Lexical Units: *auction.v, retail.v, retailer.n, sale.n, sell.v, vend.v, vendor.n*

PropBank

- PropBank: Annotation of Penn TreeBank with predicate-argument structure. Verbs come with individual roles.
- Generalisation over alternation patterns of (senses of) single verbs (the *break* case).
- No generalisation across lexeme boundaries (the *give/receive* case).
- Efficient annotation process, high inter-annotator agreement

PropBank Example

[$_{Arg0}$ *Lufthansa*] *is replacing* [$_{Arg1}$ *its 737s*] [$_{Arg2}$ *with Airbus A320s*]
[$_{Arg0}$ *Lufthansa*] *is substituting* [$_{Arg1}$ *Airbus A320s*] [$_{Arg3}$ *for its 737s*]

$$\begin{bmatrix} Pred & replace \\ Arg0 & Lufthansa \\ Arg1 & its737s \\ Arg2 & AirbusA320s \end{bmatrix} \qquad \begin{bmatrix} Pred & substitute \\ Arg0 & Lufthansa \\ Arg1 & AirbusA320s \\ Arg3 & its737s \end{bmatrix}$$

PropBank and FrameNet

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[$_{Agent}$ *Lufthansa*] *is replacing* $_{Frame:\ REPLACING}$ [$_{Old}$ *its 737s*] [$_{New}$ *with Airbus A320s*]

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