Semantic Theory

Lexical Semantics IV

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Davidson's problem

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

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 „type of argument" can be realized through different complement types, but there are verb-specific constraints on which argument can be realized by which complement, or, more specifically:
- One predicate-argument structure can be realized through different syntactic patterns, but for specific verbs, the syntactic alternations are constrained.

Some more alternations

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*

Verb Alternations (B. Levin)

Margaret cut the bread
Janet broke the vase
Terry touched the cat
Carla hit the door

middle alternation
The bread cuts easily
Crystal vases break easily
*Cats touch easily
*Doors hit easily

conative alternation
Margaret cut at the bread
*Janet broke at the vase
*Terry touched at the cat
Carla hit at the door

body-part possessor ascension alternation
Margaret cut Bill on the arm
*Janet broke Bill on the finger
Terry touched Bill on the shoulder
Carla hit Bill on the back

A Related Problem?

- The problem of syntactic argument alternations is similar to Davidson's problem: We need a method to model basic inference properties of different uses of predicates.
- There is no general solution as in the adjunct case, because lexical (syntactic and semantic) properties of the predicates are involved.
- The key to a solution is the notion of a thematic role introduced by C. Fillmore in the sixties.
- Terminology: Fillmore originally spoke about "deep cases" (in contrast to "surface cases" of syntax). In between, linguistics talk about "thematic roles", computational linguists mostly of "semantic roles".

Thematic Roles (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 an additional inventory of 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.

Thematic Roles

- A role inventory:
  - Agent, Patient (Theme, Object), Recipient, Instrument, Source, Goal, Experiencer
- An annotated example:
  - *[John]$_{ag}$ broke [the window]$_{pat}$ [with a rock]$_{inst}$*
  - *[A rock]$_{inst}$ broke [the window]$_{pat}$*
  - *[The window]$_{pat}$ broke*

Integrating Roles into Logic 1

- In standard FOL, the relation of the members of the argument set to the predicate in a predicate-argument structure is (implicitly) expressed by their order.

  break (e, j, w, r)

- In role semantics, we can write the arguments as a set indexed by thematic roles, or, equivalently, as a feature structure/ record with thematic role names as attributes.

  break ({e_{ref}, j_{ag}, w_{pat}, r_{inst}})

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

Integrating Roles into 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.

Potential of the Role Concept 1

- 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.

Establishing 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

Potential of the Role Concept 2

- 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)

Potential of the Role Concept 2

- 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
- Thematic roles support the encoding and application of additional inference rules.

Thematic Roles and Semantic Interpretation

- 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

Role Linking

- Sentences can be ambiguous with respect to role information:

  John broke the window:

  Subject can be either *Agent* or *Instrument*.
- Semantic role labeling as an important disambiguation task in computational linguistics, typically done with supervised statistical methods.

Thematic Roles in Type Theory

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: $[\lambda X.\alpha](\beta_i) \Leftrightarrow \lambda(X-\{x_i\}).\alpha^{\beta/x}$, if $x_i \in X$.

Additional clause: $\lambda^{\varnothing}.\alpha \Leftrightarrow \alpha$

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

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

Order-free λ-Abstraction

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 $\{x_{i1}, ..., x_{in}\} \in X$.

What is the appropriate role inventory?

- According to Filllmore (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.

John sold the car to Bill for 3,000€
Bill bought the car from John for 3,000€

Possible Answers

- Start with a more abstract inventory of „proto-roles“, use them for the description of concrete roles (D. Dowty)
- Use many roles: A separate role inventory for every lemma (PropBank).
- Intermediate solution: 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).

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

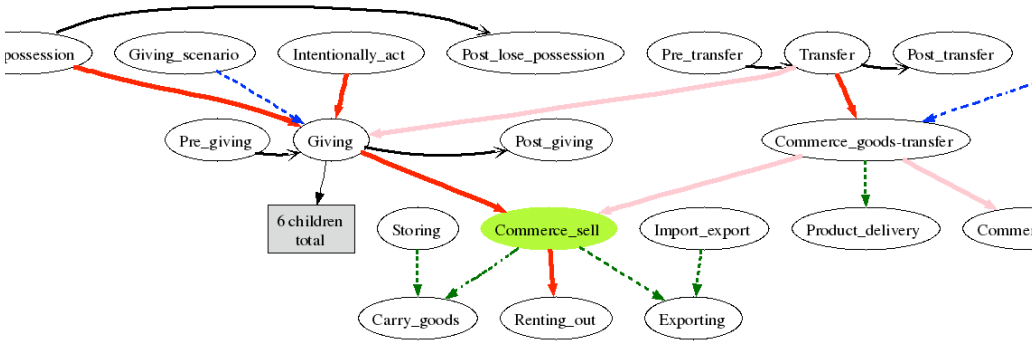
The FrameNet database consists of:

- 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*

Frame-to-Frame Relations



PropBank

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

PropBank Example: expect

Roles:

Arg0: expecter

Arg1: thing expected

Example: Transitive, active:

Portfolio managers expect further declines in interest rates.

Arg0:	Portfolio managers
REL:	expect
Arg1:	further declines in interest rates

(Slides taken over from Baker/Hajic/Palmer/Pinkal, ACL 2004)

PropBank example: *give*

Roles:

Arg0: giver

Arg1: thing given

Arg2: entity given to

Example: double object

The executives gave the chefs a standing ovation.

Arg0:	*The executives*
REL:	*gave*
Arg2:	*the chefs*
Arg1:	*a standing ovation*