Event Semantics

Week 6

Slides and materials based on the courses by
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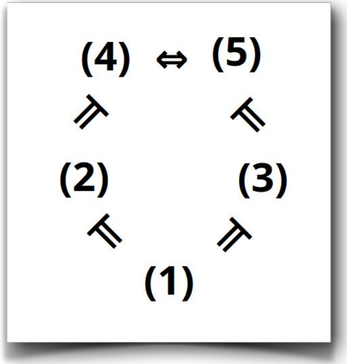
A problem with verbs and adjuncts

"the gardener killed the baron"	$\mapsto kill_1(g, b)$	$kill_1 :: \langle e, \langle e, t\rangle\rangle$
"the gardener killed the baron in the park"	$\mapsto kill_2(g, b, p)$	$kill_2 :: \langle e, \langle e, \langle e, t\rangle\rangle\rangle$
"the gardener killed the baron at midnight"	$\mapsto kill_3(g, b, m)$	$kill_3 :: \langle e, \langle e, \langle e, t\rangle\rangle\rangle$
"the gardener killed the baron at midnight in the park"	$\mapsto kill_4(g, b, m, p)$	$kill_4 :: \ldots$
"the gardener killed the baron in the park at midnight"	$\mapsto kill_5(g, b, m, p)$	$kill_5 :: \ldots$

- Ok, but how do we explain the systematic logical entailment relations between the different uses of "kill"?



Davidson's solution: verbs as event-denoting expressions

- Verbs expressing events have an additional event argument, which is not realised at linguistic surface:
  - kill $\mapsto \lambda y \lambda x \lambda e(\text{kill'}(e,x,y)) :: \langle e, \langle e, \langle e, t\rangle\rangle\rangle$ (arity ← arity + 1)

- Sentences denote sets of events:
  - $\lambda y \lambda x \lambda e(\mathit{kill}(e, x, y))(b)(g) \Rightarrow_\beta \lambda e(\mathit{kill}(e, g, b)) :: \langle e, t\rangle$

- **Existential closure** turns sets of events into truth conditions: $\lambda P \exists e(P(e)) :: \langle\langle e, t\rangle, t\rangle$
  - $\lambda P \exists e(P(e))(\lambda e_1(\mathit{kill}(e_1, g, b))) \Rightarrow_\beta \exists e(\mathit{kill}(e, g, b)) :: t$

Davisonian events and adjuncts

- Adjuncts express two-place relations between events and the respective "circumstantial information": time, location, etc.
  - *"at midnight"* $\mapsto$ $\lambda P \lambda e(P(e) \land \mathit{time}(e, \mathit{midnight}))$ :: $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$
  - *"in the park"* $\mapsto$ $\lambda P \lambda e(P(e) \land \mathit{location}(e, \mathit{the\text{-}park}))$ :: $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$

- *"the gardener killed the baron at midnight in the park"* $\mapsto$
  $\exists e(\mathit{kill}(e, g, b) \land \mathit{time}(e, \mathit{midnight}) \land \mathit{location}(e, \mathit{the\text{-}park}))$
  - $\vDash \exists e(\mathit{kill}(e, g, b) \land \mathit{time}(e, \mathit{midnight}))$
  - $\vDash \exists e(\mathit{kill}(e, g, b) \land \mathit{location}(e, \mathit{the\text{-}park}))$
  - $\vDash \exists e(\mathit{kill}(e, g, b))$

Compositional derivation

"the gardener killed the baron"

$\lambda x \lambda y \lambda e[\mathit{kill}(e, y, x)\ ](b)(g) \Rightarrow_\beta \lambda e.\mathit{kill}(e, g, b)$

"… at midnight"

$\lambda F \lambda e[F(e) \wedge \mathit{time}(e, m)\ ](\lambda e_1[\text{kill}(e_1, g, b)]) \Rightarrow_\beta \lambda e[\text{kill}(e, g, b) \wedge \text{time}(e, m)]$

"… in the park"

$\lambda R \lambda e[R(e) \wedge \mathit{loc}(e, p)](\lambda e_2[\text{kill}(e_2, g, b) \wedge \mathit{time}(e_2, m)])$

$\Rightarrow_\beta \lambda e[\mathit{kill}(e, g, b) \wedge \mathit{time}(e, m) \wedge \mathit{loc}(e, p)]$

Existential closure:

$\lambda P \exists e(P(e))(\lambda e_3[\mathit{kill}(e_3, g, b) \wedge \mathit{time}(e, m) \wedge \mathit{loc}(e, p)])$

$\Rightarrow_\beta \exists e[\mathit{kill}(e, g, b) \wedge \mathit{time}(e, m) \wedge \mathit{loc}(e, p)]$

Model structures with events

- Enriched **ontological** structures
  - **Ontology**: the area of philosophy that is concerned with identifying and describing the basic “categories of being” and their relations

- A model structure with events is a triple $M = (U, E, V)$, where:
  - U is a set of “standard individuals” or “objects”
  - E is a set of events
  - $U \cap E = \varnothing$,
  - V is an interpretation function (like in first order logic)

Sorted (first-order) logic

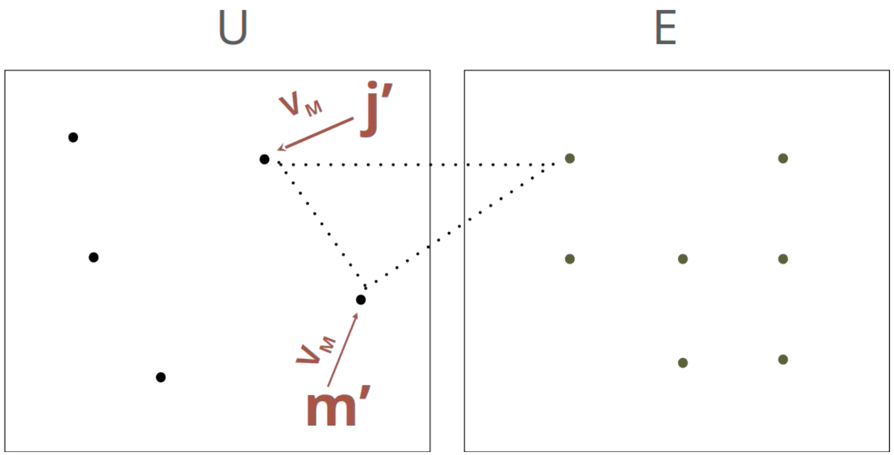
- A variable assignment *g* assigns individuals (of the correct sort-specific domain) to variables:
  - $g(x) \in U$ for $x \in VAR_U$ $VAR_U = \{x, y, z, \ldots\}$ (Object variables)
  - $g(e) \in E$ for $e \in VAR_E$ $VAR_E = \{e, e_1, e_2, \ldots\}$ (Event variables)

NB. variables from VAR_U and VAR_E are all of type *e* (in the formalisation used here)

- Quantification ranges over sort-specific domains:
  - $[[\exists x\varphi]]^{M,g} = 1$ iff there is some $d \in U$ such that $[[\varphi]]^{M,g[x/d]} = 1$
  - $[[\exists e\varphi]]^{M,g} = 1$ iff there is some $s \in E$ such that $[[\varphi]]^{M,g[e/s]} = 1$
  - (universal quantification analogous)

Interpreting events: example

- *"John kisses Mary"* $\mapsto$ $\exists e(kiss(e, j, m))$
- $[\![\exists e(kiss(e, j, m))]\!]^{M,g} = 1$
  - iff there is an $s \in E$ such that $[\![kiss(e, j, m)]\!]^{M,g[e/s]} = 1$
  - iff there is an $s \in E$ such that $(s, V_M(j), V_M(m)) \in V_M(kiss)$



Advantages of Davidsonian events

- Intuitive representation and semantic construction for adjuncts
- Uniform treatment of verb complements
- Uniform treatment of adjuncts and post-nominal modifiers
- Coherent treatment of tense information
- Highly compatible with analysis of semantic roles

Uniform treatment of verb complements

- *"Bill saw [an elephant]$_{NP}$"*
  $\mapsto$ $\exists e \exists x(\mathit{see}(e, b, x) \wedge \mathit{elephant}(x))$ — $\mathit{see} :: \langle e, \langle e, \langle e, t\rangle\rangle\rangle$

- *"Bill saw [an accident]$_{NP}$"*
  $\mapsto$ $\exists e_1 \exists e_2(\mathit{see}(e_1, b, e_2) \wedge \mathit{accident}(e_2))$ — $\mathit{see} :: \langle e, \langle e, \langle e, t\rangle\rangle\rangle$

- *"Bill saw [the children playing]$_{VP}$"*
  $\mapsto$ $\exists e_1 \exists e_2(\mathit{see}(e_1, b, e_2) \wedge \mathit{play}(e_2, \text{the-children}))$ — $\mathit{see} :: \langle e, \langle e, \langle e, t\rangle\rangle\rangle$

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Uniform treatment of adjuncts and post-nominal modifiers

- Treatment of adjuncts as predicate modifiers, analogous to attributive adjectives:
  - *"red"* ↦ $\lambda F \lambda x[F(x) \wedge \mathit{red}^*(x)]$ :: $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$
  - *"in the park"* ↦ $\lambda F \lambda e[F(e) \wedge \mathit{loc}(e, \mathit{the\text{-}park})]$ :: $\langle\langle e, t\rangle, \langle e, t\rangle\rangle$

- *"murder in the park"*:

  ↦ $\lambda F \lambda e[F(e) \wedge \mathit{loc}(e, \mathit{the\text{-}park})](\lambda e_1.\mathit{murder}(e_1)])$
- *"fountain in the park"*:

  ↦ $\lambda F \lambda x[F(x) \wedge \mathit{loc}(x, \mathit{the\text{-}park})](\lambda y.\mathit{fountain}(y)])$

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Classical Tense Logic: Modal Tense Logic

- *"John walks"* $\mapsto$ *walk(john)*
- *"John walked"* $\mapsto$ P(*walk(john)*)
- *"John will walk"* $\mapsto$ F(*walk(john)*)

- Syntax like in first-order logic, plus:
  - if φ is a WFF, then Pφ, Fφ, Hφ, Gφ are also WFFs such that:
    - $H\varphi \equiv \neg P(\neg\varphi)$
    - $G\varphi \equiv \neg F(\neg\varphi)$

- **Pφ**: φ happened in the past
- **Fφ**: φ will happen in the future
- **Hφ**: φ has always been the case
- **Gφ**: φ is always going to be the case

Model structures with tense information

- Tense model structures are quadruples M = (U, T, <, V) where
  - U is a non-empty set of individuals (the "universe")
  - T is a non-empty sets of points in time
  - $U \cap T = \varnothing$
  - < is a linear order on T
  - V is a value assignment function, which assigns to every non-logical constant α a function from T to appropriate denotations of α

- $[\![P\varphi]\!]^{M,t,g} = 1$ iff there is a $t' < t$ such that $[\![\varphi]\!]^{M,t',g} = 1$
- $[\![F\Phi]\!]^{M,t,g} = 1$ iff there is a $t' > t$ such that $[\![\varphi]\!]^{M,t',g} = 1$

Temporal relations and events

- Observation: event structure is inherently related to temporal structure
  - *“The door opened, and Mary entered the room.”*
  - *“John arrived. Then Mary left.”*
  - *“Mary left, before John arrived.”*
  - *“John arrived. Mary had left already.”*

- How can we extend event-based models with a notion of *temporal order between events*?

Temporal event structure: ordered universe of events

- A model structure with events *and* temporal precedence is defined as:
  - $M = (U, E, <, e_u, V)$, where
  - $U \cap E = \varnothing$,
  - $(- < -) \subseteq E \times E$ is an asymmetric relation (temporal precedence)
  - $e_u \in E$ is the utterance event
  - V is an interpretation function like in standard FOL
  - Notation for overlapping events: $e_1 \cdot e_2$:= neither $e_1 < e_2$ or $e_2 < e_1$

Tense in semantic construction

- We can represent tense inflection as an abstract tense operator reflecting the temporal location of the reported event relative to the utterance event
  - *PAST* $\mapsto \lambda P.\exists e[P(e) \wedge e < e_u] :: \langle\langle e, t\rangle, t\rangle$
  - *PRES* $\mapsto \lambda P.\exists e[P(e) \wedge e \cdot e_u] :: \langle\langle e, t\rangle, t\rangle$

- Standard function application results in integration of temporal information and binding of the event variable (i.e. replacing existential closure):
  - *"Bill is walking"* $\mapsto PRES(Bill\ walk) \mapsto PRES(\lambda x\lambda e[walk(e, x)](b))$
    $\Rightarrow_\beta \exists e[walk(e, b) \wedge e \cdot e_u]$
  - *"Bill walked"* $\mapsto PAST(Bill\ walk) \mapsto PAST(\lambda x\lambda e[walk(e, x)](b))$
    $\Rightarrow_\beta \exists e[walk(e, b) \wedge e < e_u]$

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Verbal arguments

- Verbal arguments with the same semantic role may syntactically appear in different positions:
  - *“John broke the window with a rock”*
  - *“a rock broke the window”*
  - *“the window broke”*

- … and we’re back to the same entailment issue:

$$\exists e(break_3(e, j, w, r)) \nvDash \exists e(break_2(e, r, w)) \nvDash \exists e(break_1(e, w))$$

Semantic/Thematic roles

"John broke the window with a rock"
(agent) (patient) (instrument)

"a rock broke the window"
(instrument) (patient)

"the window broke"
(patient)

- In standard FOL & Type Theory: thematic roles are implicitly represented by the canonical order of the arguments
- In Neo-Davidsonian event semantics: thematic roles are two-place relations between the event denoted by the verb, and an argument role filler

Semantic/Thematic roles

- "*John* broke *the window* with *a rock*"

  $\mapsto \exists e[\mathit{break}(e) \wedge \mathit{agent}(e, j) \wedge \mathit{patient}(e, w) \wedge \mathit{instrument}(e, r)]$

- "*a rock* broke *the window*"

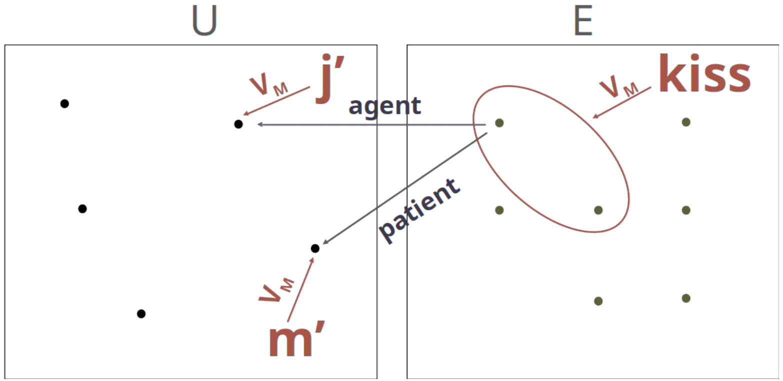
  $\mapsto \exists e[\mathit{break}(e) \wedge \mathit{patient}(e, w) \wedge \mathit{instrument}(e, r)]$

- "*the window* broke"

  $\mapsto \exists e[\mathit{break}(e) \wedge \mathit{patient}(e, w)]$

Interpreting thematic roles: example using event model

- *"John kisses Mary"* $\mapsto$ $\exists e(kiss(e) \wedge agent(e, j) \wedge patient(e, m))$
- $[\![\exists e(kiss(e) \wedge agent(e, j) \wedge patient(e, m))]\!]^{M,g} = 1$
  - iff there is an $s \in E$ s.t. $[\![kiss(e)]\!]^{M,g[e/s]} = 1$ and $[\![agent(e, j)]\!]^{M,g[e/s]} = 1$ and $[\![patient(e, m)]\!]^{M,g[e/s]} = 1$
  - iff there is an $s \in$ E s.t. $s \in V_M(kiss)$ and $(s, V_M(j)) \in V_M(agent)$ and $(s, V_M(m)) \in V_M(patient)$



Verbal differences and similarities: thematic roles

- Different verbs allow different thematic role configurations:
  - a. *"John broke the window with a rock"* (agent, patient, instrument)

    b. *"John smiled at Mary"* (agent, recipient)
  - a. *"the window broke"* (allows inanimate subject)

    b. *"the bread cut"* (does not allow inanimate subject)

- Thematic roles capture equivalences and entailment relations between different predicates:
  - a. *"Mary gave Peter the book"*

    b. *"Peter received the book from Mary"*

$$\forall e[\mathit{give}(e) \leftrightarrow \mathit{receive}(e)]$$
$$\vDash (a) \leftrightarrow (b)$$

Determining the role inventory

> *"Thematic roles form a small, closed, and universally applicable inventory conceptual argument types."* (Filmore, 1968)

- A typical role inventory might consist of the roles:
  - **Agent**, **Patient**, **Theme**, **Recipient**, **Instrument**, **Source**, **Goal**, **Beneficiary**, **Experiencer**
- But what about the following examples?
  - *"Lufthansa is replacing its 737s with Airbus 320s"*
  - *"John sold the car to Bill for 3,000€"*
  - *"Bill bought the car from John for 3,000€"*

Semantic corpora with thematic roles

- **PropBank** (Palmer et al. 2005): Annotation of Penn TreeBank with **predicate-argument structure**; separate role inventory for every lemma
  - *"[Lufthansa]*$_{\text{ARG0}}$ *is <u>replacing</u> [its 737s]*$_{\text{ARG1}}$ *with [Airbus A320s]*$_{\text{ARG2}}$*"*
  - *"[Lufthansa]*$_{\text{ARG0}}$ *is <u>substituting</u> [Airbus A320s]*$_{\text{ARG1}}$ *for [its 737s]*$_{\text{ARG2}}$*"*

Pred	replace
Arg0	Lufthansa
Arg1	its737s
Arg2	AirbusA320s

Pred	substitute
Arg0	Lufthansa
Arg1	AirbusA320s
Arg2	its737s

- **FrameNet** (Baker et al. 1998): A database of **frames** and a lexicon with frame information; a frame is a structured schema representing complex prototypical situations, events, and actions
  - *"[Lufthansa]*$_{\text{AGENT}}$ *is <u>replacing</u>*$_{\text{Frame:REPLACING}}$ *[its 737s]*$_{\text{OLD}}$ *with [Airbus A320s]*$_{\text{NEW}}$*"*
  - *"[Lufthansa]*$_{\text{AGENT}}$ *is <u>substituting</u>*$_{\text{Frame:REPLACING}}$ *[Airbus A320s]*$_{\text{NEW}}$ *for [its 737s]*$_{\text{OLD}}$*"*

Frame	REPLACING
Agent	Lufthansa
Old	its737s
New	AirbusA320s

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A problem with events and quantification: the interaction between quantifiers and existential closure

- *"John kissed Mary"*

  $\mapsto \lambda e[\mathit{kiss}(e) \wedge \mathit{agent}(e, j) \wedge \mathit{patient}(e, m)]$

  $\Rightarrow_{\text{E-CLOS}} \exists e[\mathit{kiss}(e) \wedge \mathit{agent}(e, j) \wedge \mathit{patient}(e, m)]$

- *"John kissed every girl"*

  $\mapsto \lambda e[\forall x(\mathit{girl}(x) \rightarrow \mathit{kiss}(e) \wedge \mathit{agent}(e, j) \wedge \mathit{patient}(e, x)]$

  $\Rightarrow_{\text{E-CLOS}} \exists e[\forall x(\mathit{girl}(x) \rightarrow \mathit{kiss}(e) \wedge \mathit{agent}(e, j) \wedge \mathit{patient}(e, x)]$

Two solutions to the event quantification problem

- **Solution I** (Champollion, 2010; 2015):
  - Interpret sentences as generalized quantifiers over events: $\langle\langle v, t\rangle, t\rangle$ instead of $\langle e, t\rangle$ (E-CLOS part of lexical semantics)
  - *"kiss"* $\mapsto \lambda F{::}\ \langle v, t\rangle.\ \exists e(\mathit{kiss}(e) \wedge F(e)) :: \langle\langle v, t\rangle, t\rangle \approx \{ F \mid F \cap \mathit{KISS} \neq \varnothing\}$

- **Solution II** (Winter & Zwarts, 2011; de Groote & Winter, 2014):
  - Introduce separate types for regular NPs and quantified NPs, and restrict existential closure to regular NPs

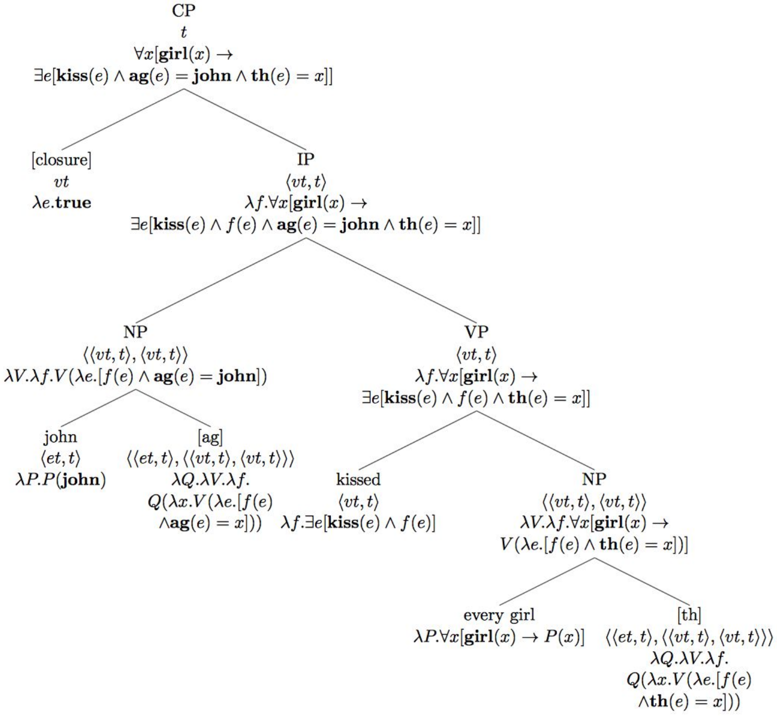
"John" $\mapsto j :: e$

"kiss" $\mapsto \lambda x \lambda y \lambda e.\mathit{kiss}(e, x, y) :: \langle e, \langle e, \langle v, t\rangle\rangle\rangle$

"every girl" $\mapsto \lambda Q.\forall x(\mathit{girl}(x) \rightarrow Q(x)) :: \langle\langle e, t\rangle, t\rangle$

E-CLOS $\mapsto \lambda P.\exists e(P(e)) :: \langle\langle v, t\rangle, t\rangle$

Solution I: Sentences as GQs over events



Solution II: Type-restriction for existential closure

$$\frac{\vdash \textsc{every} : N \to (NP \to S) \to S \qquad \vdash \textsc{girl} : N}{\vdash \textsc{every girl} : (NP \to S) \to S}\ (1)$$

$$\frac{\dfrac{\vdash \textsc{kissed} : NP \to NP \to V \qquad x : NP \vdash x : NP}{x : NP \vdash \textsc{kissed}\, x : NP \to V} \qquad \vdash \textsc{john} : NP}{x : NP \vdash \textsc{kissed}\, x\, \textsc{john} : V}\ (2)$$

$$\frac{\dfrac{\vdash \textsc{e-clos} : V \to S \qquad \begin{array}{c} \vdots\ (2) \\ x : NP \vdash \textsc{kissed}\, x\, \textsc{john} : V \end{array}}{x : NP \vdash \textsc{e-clos}\,(\textsc{kissed}\, x\, \textsc{john}) : S}}{\vdash \lambda x.\, \textsc{e-clos}\,(\textsc{kissed}\, x\, \textsc{john}) : NP \to S}\ (3)$$

$$\frac{\begin{array}{c} \vdots\ (1) \\ \vdash \textsc{every girl} : (NP \to S) \to S \end{array} \qquad \begin{array}{c} \vdots\ (3) \\ \vdash \lambda x.\, \textsc{e-clos}\,(\textsc{kissed}\, x\, \textsc{john}) : NP \to S \end{array}}{\vdash \textsc{every girl}\,(\lambda x.\, \textsc{e-clos}\,(\textsc{kissed}\, x\, \textsc{john})) : S}$$