On Anchoring Sentences in Actions
Semantics and Philosophy in Europe 4

Tillmann Pross

Institute for Natural Language Processing
University of Stuttgart

30.09.2011
Outline

1. Linguistic approaches
2. Action-Theoretic Approaches
3. Temporal Anchors
4. Summary
Linguistics vs. Action Theory

- Logical analysis of *sentences* that describe action vs. Logical analysis of *action* described by sentences
- Different focus and vocabulary of linguistic and action-theoretic approaches to the meaning of action sentences.
- This talk: how can we combine linguistic and action-theoretic approaches to action sentences?
Sentences that describe action

- [Davidson, 1967]: The logical analysis of action *sentences*
- Introduction of a new ontological sort of entities: “events” to predicate logic
  - Brutus stabbed Caesar with a knife $\Rightarrow$ Brutus stabbed Caesar.
- Events link verbs with their arguments and adjuncts on a *syntactic* level.
Davidsonian Event Semantics

- *Semantic* interpretation of Davidsonian Events?
- Interpret reference markers for events on par with reference markers for “standard” individuals
- Model contains a set of events with the help of which formulas containing event markers are evaluated
- E.g.: given a set of events $E$ structured by $<$, a universe of individuals $U$ and an interpretation function $I$,
  \[
  \lbrack R(e, x_1, \ldots, x_n) \rbrack^M, g = 1 \text{ iff } \langle g(e), g(x_1), \ldots, g(x_n) \rangle \in I(R)
  \]
- where $g$ is an assignment that maps $e$ onto an element of $E$ and $x_1, \ldots, x_n$ onto elements of $U$.
- Thus: events described by occurrences of e.g. “build a house” are events that stand in some ’build’-relation to the one who is doing the building (or the ones who are doing the building) and the thing that is built.
Fine grained event semantics?

- Davidsonian event semantics analyzes action sentences in terms of *relations* between individuals and events, not in terms of the *action* that is described.
- Causes problems when it comes to the subatomic structure of events (Moens and Steedman [1988])
Example: Tense and Aspect

- How to capture the different types of event complexes that can be described with action verbs? (“Aktionsart”, [Vendler, 1957])
  - E.g. ‘run’ vs. ‘build a house’ vs. ‘reach the top’

- How to capture the interaction between aspect, tense and events?
  - E.g. John was building a house \( \not\Rightarrow \) John built a house
  - But: John was running \( \Rightarrow \) John ran.

- Complex subatomic structure of events that can not be captured with the specification of pre-/postconditions but is related to the actions that are described.
Action described by sentences

- Logical analysis of action described by sentences
- Add modal operators to the language of propositional logic:
  - STIT [Belnap et al., 2001] e.g.: “x sees to it that p”
  - BDI [Rao and Georgeff, 1991] e.g.: “x intends that p”
- Semantic interpretation of these operators in a model theory with branching time
- Connection between action-theoretic approaches and events?
Action-theoretic approach to events

- Experimental Evidence: Segmentation of events along the assumption of underlying causal/plan-goal/intentional structures (see e.g. the collection of papers in [Shipley and Zacks, 2008])
- Conceptual: Explanation of temporal variation with causal/behavioral/intentional explanation patterns
- Linguistics: Close connection between planning and events [van Lambalgen and Hamm, 2004]
- Idea: use action logic to formalize the segmentation, constitution and internal structure of events.
  - But: Connection between natural language semantics and action formulas?
Anchors in Discourse Representation Theory (DRT)

- Anchors were introduced to DRT [Kamp, 1984] as a means to represent puzzles of reference in propositional attitude ascriptions ([Kamp, 1984-85, Asher, 1986])
- An anchor is a two-place relation between a discourse reference marker (a “floater”) and a specification of its relation of acquaintance (a “source”): \( \langle \text{floater}, \text{source} \rangle \)
Linking Natural Language Semantics and Action Theory

- Here: specify anchor sources for temporal entities with the help of operators from action logic.
- Consider not only pre-/postconditions of events but also the (sequence of) action (+ additional information on these actions such as intentions) which connect these conditions.
- This talk: adopt ideas from the BDI-interpretation of CTL* proposed by [Singh, 1994]
Temporal anchors: Syntax and Semantics

Syntactic representation of temporal anchors:

\[ e \langle e, xOPK \rangle \quad name(e) \]

- where OP is one of the operators PATH, PLAN, INT and \( K \) a DRS.

Semantic interpretation of temporal anchors:

- OP specifies a (branching) temporal structure which is assigned to \( e \) by a function \( SEM_{name}(e) \).
Branching-time Structures

A branching-time structure is a tuple $E = \{T, I, Actions\}$, where

- $T = \langle <, \text{Times} \rangle$, where $T$ is a labeled directed graph with node set $\text{Times}$, arc set $Actions$ and node labels given by $I$. In addition, we require the graph of $T$ to be a tree.
- $I$ associates times $t \in \text{Times}$ with interpretations, i.e. an information structure representing the state of affairs at $t$. 
Branching-time Structures

- **Actions** is a function from pairs $\langle t, t' \rangle$ of adjacent members of **Times** to Agents.
- **S(x)(t)** is a function from Scenarios to agents at a time. A scenario is any maximal set of moments containing the given moment, and all moments in its future along some particular branch.
- **P(x)(t)** is a function from substructured of **T**. to agents at a time and assigns plans to agents.
- **Int(x)(t)** is a function from **T** to agents at a time and assigns intentions to agents.
Example: Simple Past

Example ("Peter built a house")

\[ \langle e_0, x \rangle \text{PATH} y \]

house(y)
Temporal anchors: Model-Theoretic Semantics (1)

• Past tense: \( e \prec n \)

• \( \langle e, x \text{PATH} K \rangle \models_{M; S; t} \text{name}(e) \)
  
  \(- \) iff \( \exists [S; t; t_1] \in S(x)(t) \) sth. \( t_1 \prec n \) and \( S \in \text{SEM}_{\text{name}}(e) \) and \( \models_{M; t_1} K \)
Example: Present Progressive

Example (“Peter is building a house”)

\[
\begin{align*}
&x, e_0, n \\
&\langle e_0, x\text{INT} \rangle \\
&n \in e_0 \\
&be(e_0) \\
&Peter(x)
\end{align*}
\]

\[
\begin{align*}
&e_1 \\
&\langle e_1, x\text{PLAN} \rangle \\
&\text{house}(y) \\
&e_1 \subseteq e_0 \\
&e_0 \prec \text{beg} \ e_1 \\
&\text{build}(e_1)
\end{align*}
\]
Temporal anchors: Model-Theoretic Semantics (2)

- INT
  \[\langle e, x_{\text{INT}}K \rangle \models_{M,t} \text{name}(e)\]
  - iff \([K]_{M,t} \in \text{INT}(x)(t)\);

- PLAN: \(n \in e\)
  \[\langle e, x_{\text{PLAN}}K \rangle \models_{M,S,P,t} \text{name}(e)\]
  - iff \(\exists [S; t_0, n] \in S(x)(t)\) and \(\exists [P; n, \{t_1, \ldots, t_n\}] \in P(x)(t)\)
    sth. \((S \cup P) \in \text{SEM}_{\text{name}}(e)\) and \((\models_{M,t_1} K \land \ldots \land \models_{M,t_n} K)\)
Example: Past Progressive

Example ("Peter was building a house")

\[
\begin{align*}
&x, e_0, n \\
&\langle e_0, x\text{INT} \rangle \\
&e_0 \prec n \\
&\text{be}(e_0) \\
&\text{Peter}(x) \\
&\langle e_1, x\text{PLAN} \rangle \\
&e_1 \subseteq e_0 \\
&\text{build}(e_1) \\
&\langle y, \text{house}(y) \rangle
\end{align*}
\]
Temporal anchors: Model-Theoretic Semantics (3)

- **INT**
  \[ \langle e, x\text{INT}K \rangle \models_{M,t} \text{name}(e) \]
  \[- \text{ iff } [K]_{M,t} \in \text{INT}(x)(t); \]

- **PLAN**: \( e \prec n \)
  \[ \langle e, x\text{PLAN}K \rangle \models_{M,S,t} \text{name}(e) \]
  \[- \text{ iff } \exists[S; t, t_1] \in S(x)(t) \text{ sth. } t_1 \prec n \text{ and } S \in \text{SEM} \text{name}(e) \]
Summary

- Temporal anchors provide an action-based verb semantics.
- Main advantage from the linguistic point of view: complex structure of events takes into account not only preparatory and consequent state but also the actions that connect these states.
- Main advantage from action-theoretic point of view: possibility to take into account complex (temporal) relations between intentions, actions and goals.
Outlook

- Current Research Project: Rule-based account for the parallel construction of semantic representations and branching temporal structures in the framework of lexical DRT.
- Requires a notion of model dynamics, i.e. of the dynamic *interpretation* of semantic representations.
- Idea: The construction of temporal anchors manipulates the model theory via updates of the function that assigns temporal structures to events. ([Baltag et al., 1998], [Pross, 2010])
References I


References II


On Anchoring Sentences in Actions

Tillmann Pross

Linguistic approaches
Action-Theoretic Approaches
Temporal Anchors
Summary

References III


References IV

Aktionsart

- Activity: Focus on the sequence of action (walk)
- Accomplishment: Focus on the sequence of the action and the goal (build a house)
- Achievement: Focus on the preconditions, sequence of action and the goal (reach the top).
Syntax of EPSs

EPS vocabulary

- A set $T_R$ of EPS reference markers for things:
  $$\{a_1, \ldots, a_n, \ldots\}$$
- For each $n > 0$ a set $Rel^n$ of n-place predicate constants for names $\{C_1, \ldots, C_m, \ldots\}$
- A set $Times$ of EPS times $\{t_0, \ldots, t_n, \ldots\}$

Syntax of EPSs and EPS conditions

1. If $U \subseteq T_R \cup Times$, $Con$ a (possibly empty) set of EPS conditions then $\langle U, Con \rangle$ is an EPS

2. If $R_1 \in Rel^n$ and $a_1, \ldots, a_n, \ldots \in T_R$ then $R_1(a_1, \ldots a_n)$ is an EPS-condition

3. A time-indexed EPS is a tuple $\langle t, \langle U, Con \rangle \rangle$.

$^1$The numerical subscripts are used only to clarify the design of the EPS structure.
Anchors in DRT

- “External” anchors: Definite NPs directly contribute their reference \((x, a)\)
- “Internal” anchors: Relation of acquaintance in which reference markers stand to their reference \((x, DRS)\)