Polynomial Event Semantics

Negation

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Outline

► Introduction

Event Quantification Problem

Polynomial Event Semantics
  Existential Quantification

Negative Quantification, Negation and Ambiguities

Conclusions
Summary

An interpretation of Neo-Davidsonian semantics in which the event quantification problem does not even arise

- Denotations are constructed strictly compositionally, following the structure of the sentence
- Quantifiers are analyzed in situ
Summary

An interpretation of Neo-Davidsonian semantics in which the event quantification problem does not even arise

- Denotations are constructed strictly compositionally, following the structure of the sentence
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- No movement, no lifting, no type raising

Analysis of Quantifier/Negation ambiguities
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Neo-Davidsonian Semantics

- Brutus stabbed Caesar
- Brutus stabbed Caesar violently
Neo-Davidsonian Semantics

Brutus stabbed Caesar

\[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \]

Brutus stabbed Caesar violently
Neo-Davidsonian Semantics

- Brutus stabbed Caesar

\[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \]

- Brutus stabbed Caesar violently
Neo-Davidsonian Semantics

- Brutus stabbed Caesar

  \[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \]

- Brutus stabbed Caesar violently

  \[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \land \text{violent}(e) \]
Quantification Problem

- Brutus stabbed every senator
Quantification Problem

- Brutus stabbed every senator

\[ \exists e. \forall x. \text{senator}(x) \Rightarrow \text{stabbed}(e) \land \text{th}(e) = x \land \text{ag}(e) = \text{brutus} \]
Quantification Problem

- Brutus stabbed every senator

\[ \exists e. \forall x. \text{senator}(x) \Rightarrow \text{stabbed}(e) \land \text{th}(e) = x \land \text{ag}(e) = \text{brutus} \]

‘Collective’ reading only
Negation/Negative Quantification Problem

▶ Brutus stabbed Caesar

\[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \]

▶ Brutus stabbed nobody
Negation/Negative Quantification Problem

- Brutus stabbed Caesar
  \[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \]

- Brutus stabbed nobody
  \[ \exists e. \neg \exists x. \text{human}(x) \land \text{stabbed}(e) \land \text{th}(e) = x \land \text{ag}(e) = \text{brutus} \]
Negation/Negative Quantification Problem

- Brutus stabbed Caesar
  \[ \exists e. \text{stabbed}(e) \land \text{th}(e) = \text{caesar} \land \text{ag}(e) = \text{brutus} \]

- Brutus stabbed nobody
  \[ \exists e. \neg \exists x. \text{human}(x) \land \text{stabbed}(e) \land \text{th}(e) = x \land \text{ag}(e) = \text{brutus} \]

Sentences are contradictory, but denotations aren’t
Event Quantification Problem

The problem of scoping of the existential closure with respect to other quantificational phrases
Resolutions so far

Scope Domain Principle

*The existential quantifier for the event variable obligatory takes the lowest scope*

Implementation: Movement of the QP

(Syntactic) QR: movement because we say so

(ACG) Assigning types in the creative way, so the movement happens when computing surface form

(Semantic) Type raising in the creative way, so the movement happens when normalizing the (Montagovian) denotation
Resolutions so far

Scope Domain Principle

The existential quantifier for the event variable obligatory takes the lowest scope

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Resolutions so far

Scope Domain Principle

The existential quantifier for the event variable obligatory takes the lowest scope

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(Syntactic) QR: movement because we say so

(ACG) Assigning types in the creative way, so the movement happens when computing surface form

(Semantic) Type raising in the creative way, so the movement happens when normalizing the (Montagovian) denotation

What to do when existential closure doesn’t take the lowest scope?
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Polynomial Event Semantics

- Brutus stabbed Caesar
- Brutus stabbed Caesar violently
Polynomial Event Semantics

- Brutus stabbed Caesar

$$\text{subj }/\text{brutus } \Box \text{Stabbed} \Box \text{ob1 }/\text{caesar}$$

- Brutus stabbed Caesar violently
Polynomial Event Semantics

- Brutus stabbed Caesar

  \[ \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar} \]

- Brutus stabbed Caesar violently

  \[ \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar} \sqcap \text{Violently} \]
Polynomial Event Semantics

- Brutus stabbed Caesar

  \[ \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar} \]

- Brutus stabbed Caesar violently

  \[ \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar} \sqcap \text{Violently} \]

Entailment just from the properties of \( \sqcap \)
Polynomial Event Semantics

- Brutus stabbed Caesar

\[
\text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar}
\]

Observations

- The truth value of a sentence is the set of evidence for it (the support set)
- The query is denotation
- No existential closure (and no variables either)
- Structure of denotation matches the structure of the sentence
Existential Quantification: Motivation

The truth value of a sentence is the set of witnesses for it

▶ Brutus stabbed Caesar

subj′/brutus △ Stabbed △ ob1′/caesar
Existential Quantification: Motivation

The truth value of a sentence is the set of witnesses for it.

- Brutus stabbed Caesar

\[ \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{obl}'/\text{caesar} \]

- Brutus stabbed somebody
Existential Quantification: Motivation

The truth value of a sentence is the set of witnesses for it

- Brutus stabbed Caesar
  \[\text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar}\]

- Brutus stabbed somebody
  1. \[\text{subj}'/\text{brutus} \sqcap \text{Stabbed} \\sqcap\]
     \[\text{(ob1}'/\text{Caesar} \sqcup \text{ob1}'/\text{Antonius} \sqcup \ldots)\]
Existential Quantification: Motivation

The truth value of a sentence is the set of witnesses for it

- Brutus stabbed Caesar

  \[ \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar} \]

- Brutus stabbed somebody
  1. \( \text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \)
     \( \text{(ob1}'/\text{Caesar} \sqcup \text{ob1}'/\text{Antonius} \sqcup \ldots) \)
  2. \( (\text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{Caesar}) \sqcup \)
     \( (\text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{Antonius}) \sqcup \ldots \)
Factors

Factor
A collection of events grouped according to some criterion (e.g., by the common theme)

- Grouping of events into sets of alternatives
- The truth value of a sentence is a set of factors of witnessing events

Notation

- $c$: concept: a set of events
- $x, y$: polyconcept: a set of factors
- $\mathcal{P}c = \{c\}$
- $x \sqcup y = x \cup y$
- $x \sqcap y = \{c_x \cap c_y \mid c_x \in x, c_y \in y\}$
Polynomial Semantics

Brutus stabbed Caesar

\[
P \text{subj}'/\text{brutus} \cap P \text{Stabbed} \cap P \text{ob1}'/\text{caesar} \\
= \ P(\text{subj}'/\text{brutus} \cap \text{Stabbed} \cap \text{ob1}'/\text{caesar})
\]

\text{ob1}'/\text{caesar} \quad \text{concept: events with Caesar as a theme}

\[P \text{ob1}'/\text{caesar} = \{\text{ob1}'/\text{caesar}\} \quad \text{singleton polyconcept}\]
Polynomial Semantics

Brutus stabbed Caesar

\[ P_{\text{subj}'/\text{brutus}} \cap P_{\text{Stabbed}} \cap P_{\text{ob1}'/\text{caesar}} = P(\text{subj}'/\text{brutus} \cap \text{Stabbed} \cap \text{ob1}'/\text{caesar}) \]

\begin{align*}
\text{ob1}'/\text{caesar} & \quad \text{concept: events with Caesar as a theme} \\
P \text{ ob1}'/\text{caesar} & = \{\text{ob1}'/\text{caesar}\} \quad \text{singleton polyconcept} \\
\text{ob1}'/\text{Human} & = ???
\end{align*}
Polynomial Semantics

Brutus stabbed Caesar

\[ \mathcal{P} \text{{subj}}'/\text{brutus} \cap \mathcal{P} \text{Stabbed} \cap \mathcal{P} \text{{obl}}'/\text{caesar} \]
\[ = \mathcal{P}(\text{{subj}}'/\text{brutus} \cap \text{Stabbed} \cap \text{{obl}}'/\text{caesar}) \]

- \text{obl}'/\text{caesar} concept: events with Caesar as a theme
- \( \mathcal{P} \text{ obl}'/\text{caesar} = \{\text{obl}'/\text{caesar}\} \) singleton polyconcept
- \text{obl}'/\text{Human} = \{\text{obl}'/i \mid i \in \text{Human}\} \) a factor per human
Polynomial Semantics

Brutus stabbed Caesar

\[ \mathcal{P} \text{subj}'/\text{brutus} \cap \mathcal{P} \text{Stabbed} \cap \mathcal{P} \text{ob1}'/\text{caesar} \]

\[ = \mathcal{P}(\text{subj}'/\text{brutus} \cap \text{Stabbed} \cap \text{ob1}'/\text{caesar}) \]

\text{ob1}'/\text{caesar} \quad \text{concept: events with Caesar as a theme}
\text{\mathcal{P} ob1}'/\text{caesar} \quad = \{\text{ob1}'/\text{caesar}\} \quad \text{singleton polyconcept}
\text{ob1}'/\text{Human} \quad = \{\text{ob1}'/i \mid i \in \text{Human}\} \quad \text{a factor per human}
\\text{\mathcal{N} x} \quad = \mathcal{P} \bigcup x
\text{\mathcal{N} ob1}'/\text{Human} \quad = \mathcal{P}\{i' \mid \text{ob1}'(i', i), i \in \text{Human}\} \quad \text{singleton}
Brutus stabbed somebody

1. $\mathcal{P} \text{subj}^\prime/\text{brutus} \cap \mathcal{P} \text{Stabbed} \cap \mathcal{N} \text{ob1}^\prime/\text{Human}$
   
   $= \text{subj}^\prime/\text{brutus} \cap \text{Stabbed} \cap$
   
   $(\text{ob1}^\prime/\text{Caesar} \cup \text{ob1}^\prime/\text{Antonius} \cup \ldots)$

2. $\mathcal{P} \text{subj}^\prime/\text{brutus} \cap \mathcal{P} \text{Stabbed} \cap \text{ob1}^\prime/\text{Human}$

   $= (\text{subj}^\prime/\text{brutus} \cap \text{Stabbed} \cap \text{ob1}^\prime/\text{Caesar}) \cup$
   
   $(\text{subj}^\prime/\text{brutus} \cap \text{Stabbed} \cap \text{ob1}^\prime/\text{Antonius}) \cup \ldots$

Both denotations are built compositionally
Entailments

▶ Brutus stabbed somebody
  1a. \( P \text{ subj}'/\text{brutus} \sqcap P \text{ Stabbed} \sqcap N \text{ ob1}'/\text{Human} \)
  1b. \( P \text{ subj}'/\text{brutus} \sqcap P \text{ Stabbed} \sqcap \text{ob1}'/\text{Human} \)

▶ Brutus stabbed somebody violently
  2a. \( P \text{ subj}'/\text{brutus} \sqcap P \text{ Stabbed} \sqcap N \text{ ob1}'/\text{Human} \sqcap P \text{ Violently} \)
  2b. \( P \text{ subj}'/\text{brutus} \sqcap P \text{ Stabbed} \sqcap \text{ob1}'/\text{Human} \sqcap P \text{ Violently} \)

\[ 2a \Rightarrow 1a \]
\[ 2b \Rightarrow 1b \]
\[ 1b \Rightarrow 1a \]
\[ 2b \Rightarrow 2a \]
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Conclusions
How to Witness Non-existence

- Brutus stabbed nobody
- Brutus stabbed nobody violently

Refutation

- Technically, a negative factor
- The truth value is a set of witnesses and a set of refutations
How to Witness Non-existence

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Refutation

- Technically, a negative factor
- The truth value is a set of witnesses and a set of refutations
How to Witness Non-existence

- Brutus stabbed nobody

  1. \( P_{\text{subj'}/\text{brutus}} \cap P_{\text{Stabbed}} \cap \lnot N_{\text{ob1'}/\text{Human}} \)

- Brutus stabbed nobody violently

**Refutation**

- Technically, a negative factor

- The truth value is a set of witnesses and a set of refutations
How to Witness Non-existence

- Brutus stabbed nobody

  1. $\mathcal{P}_{subj'/brutus} \cap \mathcal{P}_{Stabbed} \cap \neg \mathcal{N}_{ob1'/Human}$

     $= \neg \mathcal{P}(\mathcal{P}_{subj'/brutus} \cap \mathcal{P}_{Stabbed} \cap \bigcup ob1'/Human)$

- Brutus stabbed nobody violently

  2. $\mathcal{P}_{subj'/brutus} \cap \mathcal{P}_{Stabbed} \cap \neg \mathcal{N}_{ob1'/Human} \cap \mathcal{P}_{Violently}$

     $= \neg \mathcal{P}(\mathcal{P}_{subj'/brutus} \cap \mathcal{P}_{Stabbed} \cap \mathcal{P}_{Violently} \cap \bigcup ob1'/Human)$

Refutation

- Technically, a negative factor
- The truth value is a set of witnesses and a set of refutations
How to Witness Non-existence

- Brutus stabbed nobody

  1. \( P_{\text{subj'}/\text{brutus}} \cap P_{\text{Stabbed}} \cap \neg N_{\text{ob1'/Human}} \)

     \[ = \neg P(\text{subj'}/\text{brutus} \cap \text{Stabbed} \cap \bigcup \text{ob1'/Human}) \]

- Brutus stabbed nobody violently

  2. \( P_{\text{subj'}/\text{brutus}} \cap P_{\text{Stabbed}} \cap \neg N_{\text{ob1'/Human}} \cap P_{\text{Violently}} \)

     \[ = \neg P(\text{subj'}/\text{brutus} \cap \text{Stabbed} \cap \text{Violently} \cap \bigcup \text{ob1'/Human}) \]

\[ 1 \Rightarrow 2 \]

Refutation

- Technically, a negative factor
- The truth value is a set of witnesses and a set of refutations
Negation

Brutus did not stab Caesar

\[ \mathcal{P} \text{ subj}'/\text{brutus} \sqcap \neg \mathcal{P} \text{ Stabbed} \sqcap \mathcal{P} \text{ ob1}'/\text{caesar} \]

\[ = \quad \neg \mathcal{P}(\text{subj}'/\text{brutus} \sqcap \text{Stabbed} \sqcap \text{ob1}'/\text{caesar}) \]
Negation and Ambiguities

- A soldier did not stab everyone
- Brutus did not accuse Caesar for one hour
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