Polynomial Event Semantics

Non-Montagovian Proper Treatment of Quantifiers

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Outline

- **Introduction**

Event Semantics, peculiarly

Key idea: Event groups

Polynomial Event Semantics

Compositional Poly-concept Semantics

Conclusions

Introduction

Event Semantics

Quantification

Introduction

Event Semantics

Davidson

Quantification

Montague

Introduction

Event Semantics

Davidson

Quantification

Montague

`http://okmij.org/ftp/gengo/`

Summary

No

- No Montague
- No continuations
- No monads, applicatives, category theory
- No lambda-calculus
- No variables

Mere simple set theory and algebra

- Universal, existential and counting quantification with all the benefits of event semantics
- Compositional semantics
- In situ analysis of quantifiers
- Quantifier ambiguity

Outline

Sample Domain

Individuals	students, classes, days of week, events
Concepts	Student : {bill, john, seth} Cut : events e1 through e6 Class : {peMo, peWd, peFr}
Roles	subj', ob1' as in the table below

event	subj	obj	event	subj	obj
e1	bill	peMo	e4	john	peMo
e2	bill	peWd	e5	seth	peWd
e3	bill	peFr	e6	seth	peFr

Event

- `e1`

Event

- e1
- [subj: Bill; obj: peMo; action: cut;
  manner: deliberately; time: yesterday; . . .]

Event

- e1
- [subj: Bill; obj: peMo; action: cut;
  manner: deliberately; time: yesterday; . . .]
- bM

Event Semantics

Sentence

Bill cut PeMo.

Tagged sentence (Penn Historical Corpora, etc.)

```
(IP-MAT (NP-Or (NPR Bill)) (Or cut) (NP-OB1 (NPR PEMo)))
```

Denotation

$\mathsf{subj'}/\{\mathsf{bill}\} \sqcap (\mathsf{Cut} \sqcap \mathsf{obj1'}/\{\mathsf{peMo}\})$

Event Semantics

Sentence

Bill cut PeMo.

Tagged sentence (Penn Historical Corpora, etc.)

```
(IP-MAT (NP-Or (NPR Bill)) (Or cut) (NP-OB1 (NPR PEMo)))
```

Denotation

$\mathsf{subj'/\{bill\}} \sqcap (\mathsf{Cut} \sqcap \mathsf{obj1'/\{peMo\}})$

Model

$\{\mathsf{bM}\}$

Event Semantics

Sentence

Bill cut PeMo.

Tagged sentence

```
(IP-MAT (NP-SBJ (NPR Bill)) (VBD cut) (NP-OB1 (NPR PEMo)))
```

Denotation

$\mathsf{subj'/\{bill\}} \sqcap (\mathsf{Cut} \sqcap \mathsf{obj1'/\{peMo\}})$

Syntax $\leftrightarrow$ Denotation

Event Semantics

Sentence

Bill cut PeMo deliberately.

Denotation

$\mathsf{subj'/\{bill\}} \sqcap (\mathsf{Cut} \sqcap \mathsf{obj1'/\{peMo\}}) \sqcap \mathsf{Deliberate}$

Syntax $\leftrightarrow$ Denotation

Entailment

Event Semantics

Sentence

Bill cut PeMo after he moved to the new school.

Denotation

$$\mathsf{subj'/\{bill\}} \sqcap (\mathsf{Cut} \sqcap \mathsf{obj1'/\{peMo\}}) \sqcap \mathsf{after'/}(\mathsf{subj'/\{bill\}} \sqcap (\mathsf{Move} \sqcap \mathsf{obj1'/\{theNewSchool\}}))$$

Syntax $\leftrightarrow$ Denotation

Entailment

Outline

Problem

Bill cut PeMo

$\mathsf{subj'/\{bill\} \sqcap (Cut \sqcap obj1'/\{peMo\})}$

Bill cut every class

???

Bill cut two classes

???

Bill cut no classes

???

Event Groups

Bill cut every class

Evidence (Model)

$$\langle \mathsf{bM}, \mathsf{bW}, \mathsf{bF} \rangle$$

Event Groups and Factors

Bill cut two classes

(At least two classes)

Evidence (Model):

$$\langle \mathsf{bM}, \mathsf{bW} \rangle$$

Event Groups and Factors

Bill cut two classes

(At least two classes)

Evidence (Model):

$$\lceil \langle \mathsf{bM}, \mathsf{bW} \rangle \ \langle \mathsf{bW}, \mathsf{bF} \rangle \ \langle \mathsf{bM}, \mathsf{bF} \rangle \rceil$$

Event Groups and Factors

Bill cut two classes
(At least two classes)

Evidence (Model): internal choice

$$\{\lceil\langle \mathsf{bM}, \mathsf{bW}\rangle\ \langle \mathsf{bW}, \mathsf{bF}\rangle\ \langle \mathsf{bM}, \mathsf{bF}\rangle\rceil\}$$

Evidence (Model): external choice

$$\{\lceil\langle \mathsf{bM}, \mathsf{bW}\rangle\rceil, \lceil\langle \mathsf{bW}, \mathsf{bF}\rangle\rceil, \lceil\langle \mathsf{bM}, \mathsf{bF}\rangle\rceil\}$$

Counting (and existential) quantifiers are inherently ambiguous

Outline

Poly-Concept

Syntax

Concept	c	
Poly-Concept	$x, y ::=$	$\bot \mid \mathcal{P}c \mid \mathcal{N}x \mid x \sqcup y \mid x \sqcap y \mid x \otimes y$

Set-theoretic semantics

Concept	c	A set of individuals	$\{\mathsf{bM}, \mathsf{bW}\}$
Poly-Concept	x, y	A set of factors	$\{\lceil\langle \mathsf{bM}, \mathsf{bW}\rangle\ \langle \mathsf{bM}, \mathsf{bW}\rangle\rceil\}$
Factor	d	A set of groups	$\lceil\langle \mathsf{bM}, \mathsf{bW}\rangle\ \langle \mathsf{bM}, \mathsf{bW}\rangle\rceil$
Group	g	A set of individuals	$\langle \mathsf{bM}, \mathsf{bW}\rangle$

Poly-Concept Operations

$\mathcal{P}$Student

$$\{\lceil\langle \mathsf{bill}\rangle\ \langle \mathsf{john}\rangle\ \langle \mathsf{seth}\rangle\rceil\}$$

Narrowing (flattening): $\mathcal{N}x$

$$\bigcup_{d\in x} d$$

Additive: $x \sqcup y$

$$x \cup y$$

ordinary set-union (of the sets of factors)

Poly-Concept Operations: Group formation

Poly-concept multiplication $x \otimes y$

$$\{d \otimes d' \mid d \in x, d' \in y\}$$

(suppressing empty factors)

Factor multiplication $d \otimes d'$

$$\{g \cup g' \mid g \in d, g' \in d', g \cap g' = \varnothing\}$$

$(\mathcal{P}\mathsf{Student})^n$

$(\mathcal{P}\mathsf{Student})^1$	$\{\lceil\langle \mathsf{bill}\rangle\ \langle \mathsf{john}\rangle\ \langle \mathsf{seth}\rangle\rceil\}$
$(\mathcal{P}\mathsf{Student})^2$	$\{\lceil\langle \mathsf{bill}, \mathsf{john}\rangle\ \langle \mathsf{john}, \mathsf{seth}\rangle\ \langle \mathsf{bill}, \mathsf{seth}\rangle\rceil\}$
$(\mathcal{P}\mathsf{Student})^3$	$\{\lceil\langle \mathsf{bill}, \mathsf{john}, \mathsf{seth}\rangle\rceil\}$
$(\mathcal{P}\mathsf{Student})^4$	$\bot$

Poly-Concept Operations: Intersection

Poly-concept intersection $x \sqcap y$

$$\{d \sqcap d' \mid d \in x, d' \in y\}$$

(suppressing empty factors)

Factor intersection $d_1 \sqcap d_2$

$$d_1^{|d_2|} \cap d_2^{|d_1|}$$

$|d|$ is the cardinality of d's groups (all groups within a factor have the same cardinality)

Why can't we just take the intersection of factors?

Outline

Compositional Semantics

From a tree to the poly-concept

Adjective, Adverb	$\mathcal{P}$ Concept
Verb	$\mathcal{P}$ Concept
Adjoin	$\sqcap$

Poly-concept for NP in a role (e.g., subj)

Proper noun	$\mathcal{P}(\mathsf{subj'}/\{\mathsf{properNoun}\})$
At least k N	$\bigcup_{s\subset \mathsf{CN},\lvert s\rvert=k} \prod_{i\in s} \mathcal{P}(\mathsf{subj'}/\{\mathsf{i}\})$
	$\mathcal{N}x$ x is the poly-concept above
an N	$\bigcup_{i\in \mathsf{CN}} \mathcal{P}(\mathsf{subj'}/\{\mathsf{i}\})$
	$\mathcal{P}(\mathsf{subj'}/\mathsf{CN})$
Every N	$\prod_{i\in \mathsf{CN}} \mathcal{P}(\mathsf{subj'}/\{\mathsf{i}\})$

Counting and existentials are inherently ambiguous

Universals

"cut every class"

$$\{\lceil\langle \mathsf{bM}, \mathsf{bW}, \mathsf{bF}\rangle\ \langle \mathsf{bM}, \mathsf{bW}, \mathsf{sF}\rangle\ \langle \mathsf{bM}, \mathsf{sW}, \mathsf{bF}\rangle\ \langle \mathsf{bM}, \mathsf{sW}, \mathsf{sF}\rangle\ \langle \mathsf{jM}, \mathsf{bW}, \mathsf{bF}\rangle\ \langle \mathsf{jM}, \mathsf{bW}, \mathsf{sF}\rangle\ \langle \mathsf{jM}, \mathsf{sW}, \mathsf{bF}\rangle\ \langle \mathsf{jM}, \mathsf{sW}, \mathsf{sF}\rangle\rceil\}$$

"Bill cut every class"

$$\{\lceil\langle \mathsf{bM}, \mathsf{bW}, \mathsf{bF}\rangle\rceil\}$$

"Every student cut every class"

$$\bot$$

Ambiguity

"cut every class"

$$\{\lceil\langle \mathsf{bM}, \mathsf{bW}, \mathsf{bF}\rangle\ \langle \mathsf{bM}, \mathsf{bW}, \mathsf{sF}\rangle\ \langle \mathsf{bM}, \mathsf{sW}, \mathsf{bF}\rangle\ \langle \mathsf{bM}, \mathsf{sW}, \mathsf{sF}\rangle\ \langle \mathsf{jM}, \mathsf{bW}, \mathsf{bF}\rangle\ \langle \mathsf{jM}, \mathsf{bW}, \mathsf{sF}\rangle\ \langle \mathsf{jM}, \mathsf{sW}, \mathsf{bF}\rangle\ \langle \mathsf{jM}, \mathsf{sW}, \mathsf{sF}\rangle\rceil\}$$

"subj/A student"

$$\begin{array}{rc} 1 & \{\lceil\langle \mathsf{bM}\rangle\ \langle \mathsf{bW}\rangle\ \langle \mathsf{bF}\rangle\ \langle \mathsf{jM}\rangle\ \langle \mathsf{sW}\rangle\ \langle \mathsf{sF}\rangle\rceil\} \\ 2 & \{\lceil\langle \mathsf{bM}\rangle\ \langle \mathsf{bW}\rangle\ \langle \mathsf{bF}\rangle\rceil, \lceil\langle \mathsf{jM}\rangle\rceil, \lceil\langle \mathsf{sW}\rangle\ \langle \mathsf{sF}\rangle\rceil\} \end{array}$$

"A student cut every class"

$$\begin{array}{rc} 1 & \text{all groups of three events (see above)} \\ 2 & \{\lceil\langle \mathsf{bM}, \mathsf{bW}, \mathsf{bF}\rangle\rceil\} \end{array}$$

Pseudo-ambiguity

"A student cut a class"

1 $\{\lceil\langle \mathsf{bM}\rangle\ \langle \mathsf{bW}\rangle\ \langle \mathsf{bF}\rangle\ \langle \mathsf{jM}\rangle\ \langle \mathsf{sW}\rangle\ \langle \mathsf{sF}\rangle\rceil\}$

2 $\{\lceil\langle \mathsf{bM}\rangle\ \langle \mathsf{bW}\rangle\ \langle \mathsf{bF}\rangle\rceil, \lceil\langle \mathsf{jM}\rangle\rceil, \lceil\langle \mathsf{sW}\rangle\ \langle \mathsf{sF}\rangle\rceil\}$

3 $\{\lceil\langle \mathsf{bM}\rangle\ \langle \mathsf{jM}\rangle\rceil, \lceil\langle \mathsf{bW}\rangle\ \langle \mathsf{sW}\rangle\rceil, \lceil\langle \mathsf{bF}\rangle\ \langle \mathsf{sF}\rangle\rceil\}$

4 $\{\lceil\langle \mathsf{bM}\rangle\rceil, \lceil\langle \mathsf{bW}\rangle\rceil, \lceil\langle \mathsf{bF}\rangle\rceil, \lceil\langle \mathsf{jM}\rangle\rceil, \lceil\langle \mathsf{sW}\rangle\rceil, \lceil\langle \mathsf{sF}\rangle\rceil\}$

Counting ambiguity

"Two students cut every class"

$$1 \quad \{\lceil\langle \mathsf{bM}, \mathsf{bW}, \mathsf{bF}, \mathsf{jM}, \mathsf{sW}, \mathsf{sF}\rangle\rceil\}$$

$$2 \qquad\qquad \bot$$

Negation

- Bill cut no class
- Bill did not cut a class
- Bill has not cut every class
- Bill cut exactly two classes
- Bill did not cut exactly two classes

Outline

Conclusions

PTQ without Montague

- with events, without variables
- with quantifier ambiguity, without QR (or any movements)

Semantics

- model-theoretical: triple sets
- proof-theoretical: algebra

Future Work

- Fully work out negation
- Infinitival components?
- Connection with collective readings of quantifiers?
- Semantics of plurals?
- Modalities and free choice?