QNP Textual Entailment with Polynomial Event Semantics

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Outline

Overview

FraCaS Textual Entailment & Event Semantics

\+ Event semantics is good for textual entailment

– FraCaS (Sec 1) has a whole variety of quantifiers:

- a, some, every, all,
- several, many, at least three,
- no, at most ten,
- most, few

Event semantics is not good at quantifiers

? FraCaS (Sec 1) has copula, existence and relative clauses: not action sentences

Does event semantics even apply?

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not action sentences
Does event semantics even apply?

Polynomial Event Semantics

Event semantics meant to deal with quantifiers
(at least simple universal and existential)

Outline

FraCaS

The poster problem

FraCaS 023

Some delegates finished the survey on time.

Some delegates finished the survey.

Goal

Check the entailment of the last sentence of the problem from the preceding sentences

Polynomial Event Semantics

Some delegates finished the survey on time.

$$(\mathsf{subj}'/\,(\mathcal{G}_{\mathsf{N}>1}\,\mathsf{Delegate}))\sqcap(\mathcal{P}\,\{\mathsf{Finished}'\})\sqcap$$
$$(\mathsf{ob1}'/\,(\mathcal{P}\mathsf{Survey}))\sqcap(\mathcal{P}\,\{\mathsf{OnTime}'\})$$

Polynomial Event Semantics

Some delegates finished the survey on time.

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- Sets of individuals (concepts): Delegate, Survey
- Sets of events: Finished′, OnTime′
- Sets of non-empty event sets (e-concepts): {Finished′}
- Turn (inject) concepts to polyconcepts: $\mathcal{P}$
- Grouping: $\mathcal{G}_N$ (in fact, $\mathcal{P} = \mathcal{G}_1$)
- Thematic functions and relations: subj′, ob1′
- Polyconcept intersection: $\sqcap$

Polynomial Event Semantics

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- Denotation is *not* a (FOL, Ty2) logic formula
- No variables (no event variable)
- The denotation is a query (of a database of events in the world)
- Its result is *the set of events which witness the sentence*

Polynomial Event Semantics

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- Compositional (denotation matches the sentence, in form)
- Each constituent is represented by a polyconcept
- quantifiers analyzed in situ

Polynomial Event Semantics: Entailment

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$Q_1 \Longrightarrow Q_2$ iff

$Q_1 \neq \bot \Longrightarrow Q_2 \neq \bot$ for any event database

Polynomial Event Semantics: Entailment

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Algebraically: $x \sqcap y \Longrightarrow x$

Didn't even need to know what $\mathcal{G}_N$ is exactly

A bit of formality

$\sqcap$: basically, like set intersection

$$c_1 \sqcap c_2 = c_1 \cap c_2 \qquad \mathcal{P}d_1 \sqcap \mathcal{P}d_2 = \mathcal{P}(d_1 \sqcap d_2)$$
$$d_1 \sqcap d_2 = \{c_1 \cap c_2 \mid c_1 \in d_1, c_2 \in d_2, c_1 \cap c_2 \neq \varnothing\}$$
$$\mathcal{P}d = \bot \text{ iff } d = \varnothing$$

Grouping

$$\mathcal{G}_N\, d_1 \sqcap \mathcal{P}d_2 = \mathcal{G}_N\, (d_1 \sqcap \{\cup d_2\}) \qquad \mathcal{G}_N\, d = \bot \text{ iff } |d| < N$$

A bit of formality

$$\mathsf{subj}'/\,\mathcal{G}_{\mathsf{N}>1}\,\mathsf{Delegate} \sqcap \mathcal{P}\,\{\mathsf{Finished}'\} \;\sqcap\; \mathsf{ob1}'/\,(\mathcal{P}\mathsf{Survey})$$

$$= \mathcal{G}_N(\mathsf{subj}'/\,\mathsf{Delegate} \sqcap \{\mathsf{Finished}' \cap \bigcup \mathsf{ob1}'/\,\mathsf{Survey}\})$$

$$= \mathcal{G}_N\{\text{nonempty}\;\; \mathsf{subj}'/\,i_d \cap \mathsf{Finished}' \cap \bigcup \mathsf{ob1}'/\,\mathsf{Survey} \mid i_d \in \mathsf{Delegate}\}$$

non-$\bot$ just in case there are records in the event database of at least N delegates having finished the survey

Solved Similarly

017 An Irishman won the Nobel prize for literature.
An Irishman won a Nobel prize.

024 Many delegates obtained interesting results
from the survey.
Many delegates obtained results from the survey.

025 Several delegates got the results published in
major national newspapers.
Several delegates got the results published.

031 At least three commissioners spend a lot of time at home.
At least three commissioners spend time at home.

Just by $x \sqcap y \Longrightarrow x$

Negative Quantification

No delegate finished the report on time.

No delegate finished the report.

Negative Quantification

No delegate finished the report on time.

$\mathsf{subj}'/\,\neg\mathcal{P}\mathsf{Delegate} \sqcap \mathcal{P}\,\{\mathsf{Finished}'\} \sqcap$
$\mathsf{ob1}'/\,\mathcal{P}\,\mathsf{Report} \sqcap \mathcal{P}\,\{\mathsf{OnTime}'\}$

No delegate finished the report.

$\mathsf{subj}'/\,\neg\mathcal{P}\mathsf{Delegate} \sqcap \mathcal{P}\,\{\mathsf{Finished}'\} \sqcap$
$\mathsf{ob1}'/\,\mathcal{P}\,\mathsf{Report}$

- Query for a counter-examples (refutation)
- $\neg x$: set (polyconcept) marked as a refutation

Negative Quantification

No delegate finished the report on time.

$$\neg(\mathsf{subj}'/\,\mathcal{P}\mathsf{Delegate} \sqcap \mathcal{P}\,\{\mathsf{Finished}'\} \sqcap \mathsf{ob1}'/\,\mathcal{P}\,\mathsf{Report} \sqcap \mathcal{P}\,\{\mathsf{OnTime}'\})$$

No delegate finished the report.

$$\neg(\mathsf{subj}'/\,\mathcal{P}\mathsf{Delegate} \sqcap \mathcal{P}\,\{\mathsf{Finished}'\} \sqcap \mathsf{ob1}'/\,\mathcal{P}\,\mathsf{Report})$$

- Query for a counter-examples (refutation)
- $\neg x$: set (polyconcept) marked as a refutation
- Entailment of refutations

Downward Monotonicity

At most ten commissioners spend a lot of time at home.

At most ten commissioners spend time at home.

Downward Monotonicity

At most ten commissioners spend a lot of time at home.

At most ten commissioners spend time at home.

$$\mathsf{AtMost10}\ c = \neg(\mathcal{G}_{11}\ c)$$

Solved Similarly

038 No delegate finished the report.
Some delegate finished the report on time.

070 No delegate finished the report on time.
Some Scandinavian delegate finished the report on time.

Negation

- Negative quantification
- Sentential negation: "It is not the case that"
- VP negation

Negation

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- VP negation

negative sentences mean what they deny

- Affirmative sentence: affirms certain events
- A sentence with negation: denies certain events
  and whose appearance would thus cause contradiction

Analysis of Negation

A delegate finished *no* report.

A delegate *didn't* finish a report.

A delegate *didn't* finish *any* report.

A delegate *didn't FINISH* a report.

Analysis of Negation

A delegate finished *no* report.

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A delegate *didn't FINISH* a report.

$\ldots \sqcap \left(\mathsf{action}'/\,\mathcal{P}\mathsf{Action} \otimes \neg\,\mathsf{action}'/\,\{\mathsf{finished}\}\right) \sqcap \ldots$

many problems

Many British delegates obtained interesting results from the survey.

Many delegates obtained interesting results from the survey.

many problems

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from the survey.

Many delegates obtained interesting results from the survey.

$\mathsf{Many}\ c = \mathcal{G}_N\ c$ *or* $\mathsf{Many}\ c = \mathcal{G}_{\alpha|c|}\ c$

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$$\mathsf{Most}\ c = \mathcal{G}_{\alpha|c|}\ c \quad \text{where } \alpha > 0.5$$

$$\mathsf{Few}\ c = \neg(\mathsf{Many}\ c)$$

Outline

Copular Clauses

A Swede won a Nobel prize.

Every Swede is a Scandinavian.

A Scandinavian won a Nobel prize.

Outline

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

There was an Italian who became the world's greatest tenor.

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

An Italian who became the world's greatest tenor existed.

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

An Italian who became the world's greatest tenor existed.

world's greatest tenor

WGT

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

An Italian who became the world's greatest tenor existed.

became the world's greatest tenor

$\mathcal{P}\,\{\mathsf{Became}'\} \sqcap \mathsf{ob1}' / \mathcal{P}\,\mathsf{WGT}$

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

An Italian who became the world's greatest tenor existed.

who became the world's greatest tenor

$\overline{\mathsf{subj}}'/\ (\mathcal{P}\,\{\mathsf{Became}'\} \sqcap \mathsf{ob1}'/\,\mathcal{P}\,\mathsf{WGT})$

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

An Italian who became the world's greatest tenor existed.

who became the world's greatest tenor

$\overline{\mathsf{subj}}'/\ (\mathcal{P}\,\{\mathsf{Became}'\} \sqcap \mathsf{ob1}'/\,\mathcal{P}\,\mathsf{WGT})$

$(a)\quad \overline{\mathsf{subj}}'/\,\mathsf{subj}'/\,c = c$

$(b)\quad d \Longrightarrow \mathsf{subj}'/\,\overline{\mathsf{subj}}'/\,d$

Existence and Subject Relative Clauses

An Italian became the world's greatest tenor.

An Italian who became the world's greatest tenor existed.

$$\mathsf{subj}'/\ (\mathcal{P}\ \mathsf{Italian} \sqcap (\overline{\mathsf{subj}}'/\ (\mathcal{P}\ \{\mathsf{Became}'\} \sqcap \mathsf{ob1}'/\ \mathcal{P}\ \mathsf{WGT}))) \sqcap \mathcal{P}\ \{\mathsf{Be}'\}$$

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Outline

Conclusions

- Polynomial event semantics applied to textual entailment problems in Sec.1 of FraCaS
- Prior work extended to the gamut of GQ, copula, existential, and subject relative clauses
- Polynomial event semantics as algebra
- Deductive system for deciding entailments

Future work

The mechanical implementation