QNP Textual Entailment with Polynomial Event Semantics

Oleg Kiselyov    Haruki Watanabe

Tohoku University, Japan

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Outline

Introduction

Generalized Quantifiers
  Negative Quantification and Downward Monotonicity
  Negation
  Many, Most, Few

Copula Clauses

Existence and Subject Relative Clauses

Conclusions
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?
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,
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  ➤ 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?

**Polynomial Event Semantics**

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

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
Some delegates finished the survey on time.

\[(\text{subj}'/ (G_{N>1} \text{ Delegate})) \sqcap (P \{\text{Finished}'\}) \sqcap (\text{ob1}'/ (P \text{Survey})) \sqcap (P \{\text{OnTime}'\})\]
Some delegates finished the survey on time.

$$\text{subj}'/ \mathcal{G}_{N>1} \text{ Delegate} \sqcap \mathcal{P} \{\text{Finished'}\} \sqcap$$
$$\text{ob1}'/ \mathcal{P}\text{Survey} \sqcap \mathcal{P} \{\text{OnTime'}\}$$
Polynomial Event Semantics

Some delegates finished the survey on time.

\[ \text{subj}'/ G_{N>1} \text{Delegate} \sqcap \mathcal{P} \{\text{Finished}'\} \sqcap \]
\[ \text{ob1}'/ \mathcal{P} \text{Survey} \sqcap \mathcal{P} \{\text{OnTime}'\} \]

- 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 \text{ (in fact, } \mathcal{P} = \mathcal{G}_1 \text{)}
- Thematic functions and relations: subj', ob1'
- Polyconcept intersection: \sqcap
Some delegates finished the survey on time.

\[
\text{subj}'/ G_{N>1} \text{Delegate} \sqcap \mathcal{P}\{\text{Finished}'\} \sqcap \\
\text{ob1}'/ \mathcal{P}\text{Survey} \sqcap \mathcal{P}\{\text{OnTime}'\}
\]

- 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*
Some delegates finished the survey on time.

\[ \text{subj}' / G_{N>1} \text{ Delegate } \sqcap \mathcal{P} \{\text{Finished}'\} \sqcap \]
\[ \text{ob1}' / \mathcal{P} \text{ Survey } \sqcap \mathcal{P} \{\text{OnTime}'\} \]

- Compositional (denotation matches the sentence, in form)
- Each constituent is represented by a polyconcept
- Quantifiers analyzed in situ
Some delegates finished the survey on time.

\[ \text{subj}' / G_{N>1} \text{ Delegate} \sqcap \mathcal{P} \{\text{Finished}'\} \sqcap \text{ob1}' / \mathcal{P}\text{Survey} \sqcap \mathcal{P} \{\text{OnTime}'\} \]

Some delegates finished the survey.

\[ \text{subj}' / G_{N>1} \text{ Delegate} \sqcap \mathcal{P} \{\text{Finished}'\} \sqcap \text{ob1}' / \mathcal{P}\text{Survey} \]
Polynomial Event Semantics: Entailment

Some delegates finished the survey on time.

\[
\text{subj}'/ G_{N>1} \text{ Delegate} \sqcap P \{\text{Finished}'\} \sqcap \\
\text{ob1}'/ P\text{Survey} \sqcap P \{\text{OnTime}'\}
\]

Some delegates finished the survey.

\[
\text{subj}'/ G_{N>1} \text{ Delegate} \sqcap P \{\text{Finished}'\} \sqcap \\
\text{ob1}'/ P\text{Survey}
\]

\[Q_1 \implies Q_2 \text{ iff } Q_1 \neq \bot \implies Q_2 \neq \bot\] for any event database
Some delegates finished the survey on time.

subj′/ G_{N>1} Delegate \sqcap \mathcal{P} \{\text{Finished}'\} \sqcap
\quad \text{ob1'}/ \mathcal{P} \text{Survey} \sqcap \mathcal{P} \{\text{OnTime}'\}

Some delegates finished the survey.

subj′/ G_{N>1} Delegate \sqcap \mathcal{P} \{\text{Finished}'\} \sqcap
\quad \text{ob1'}/ \mathcal{P} \text{Survey}

Algebraically: \ x \sqcap y \Rightarrow x

Didn’t even need to know what \ G_N \ is exactly
A bit of formality

\[ c_1 \cap c_2 = c_1 \cap c_2 \quad \mathcal{P}d_1 \cap \mathcal{P}d_2 = \mathcal{P}(d_1 \cap d_2) \]
\[ d_1 \cap d_2 = \{c_1 \cap c_2 \mid c_1 \in d_1, c_2 \in d_2, c_1 \cap c_2 \neq \emptyset\} \]
\[ \mathcal{P}d = \bot \text{ iff } d = \emptyset \]

Grouping

\[ \mathcal{G}_N d_1 \cap \mathcal{P}d_2 = \mathcal{G}_N (d_1 \cap \{\cup d_2\}) \quad \mathcal{G}_N d = \bot \text{ iff } |d| < N \]
A bit of formality

$$\text{subj}'/ \mathcal{G}_{N>1} \text{Delegate} \cap \mathcal{P} \{\text{Finished}'\} \cap \text{ob1}'/ (\mathcal{P} \text{Survey})$$

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

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

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 \( x \lor y \longrightarrow x \)
Negative Quantification

No delegate finished the report on time.

No delegate finished the report.
Negative Quantification

No delegate finished the report on time.

subj’/ ¬PDelegate ⊓ P \{Finished’\} ⊓ ob1’/ P Report ⊓ P \{OnTime’\}

No delegate finished the report.

subj’/ ¬PDelegate ⊓ P \{Finished’\} ⊓ ob1’/ P Report

- Query for a counter-examples (refutation)
- ¬x: set (polyconcept) marked as a refutation
Negative Quantification

No delegate finished the report on time.
\[\neg(\text{subj}'/ \ P\text{Delegate} \sqcap P \{\text{Finished}'\} \sqcap \text{ob1}'/ P \text{Report} \sqcap P \{\text{OnTime}'\})\]

No delegate finished the report.
\[\neg(\text{subj}'/ \ P\text{Delegate} \sqcap P \{\text{Finished}'\} \sqcap \text{ob1}'/ P \text{Report})\]

- 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.

\[
\text{AtMost10 } c = \neg (G_{11} c)
\]
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

- Negative quantification
- Sentential negation: “It is not the case that”
- 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.
A delegate finished *no* report.

\[
\text{subj}^{'}/\mathcal{P}\text{Delegate} \sqcap \mathcal{P}\{\text{Finished}^{'}\} \sqcap \neg \text{ob1}^{'}/\mathcal{P}\text{Report}
\]

A delegate *didn’t* finish a report.

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

A delegate *didn’t* \textit{FINISH} a report.
A delegate finished *no* report.

$$\bigcup_{i \in \text{Delegate}} \neg \bigcup_{j \in \text{Report}} \text{subj}'/i \cap \text{Finished}' \cap \text{ob1}'/j$$

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.

subj' / $P_{\text{Delegate}} \sqcap P \{\text{Finished}'\} \sqcap \neg \text{ob1'} / P_{\text{Report}}$

A delegate didn’t finish a report.

subj' / $P_{\text{Delegate}} \sqcap \neg P \{\text{Finished}'\} \sqcap \text{ob1'} / P_{\text{Report}}$

A delegate didn’t finish any report.

A delegate didn’t FINISH a report.
A delegate finished no report.
\[
\llbracket \neg \llbracket \text{subj}'/i \cap \text{Finished}' \cap \text{ob1}'/j \rrbracket \rrbracket
\]

\[i \in \text{Delegate} \quad j \in \text{Report}\]

A delegate didn’t finish a report.
\[
\llbracket \llbracket \neg (\text{subj}'/i \cap \text{Finished}' \cap \text{ob1}'/j) \rrbracket \rrbracket
\]

\[i \in \text{Delegate} \quad j \in \text{Report}\]

A delegate didn’t finish any report.

A delegate didn’t finish FINISH a report.
Analysis of Negation

A delegate finished *no* report.
subj′/Delegate ⊓ P {Finished′} ⊓ ¬ ob1′/Report

A delegate *didn’t* finish a report.
subj′/Delegate ⊓ ¬ P {Finished′} ⊓ ob1′/Report

A delegate *didn’t* finish *any* report.
subj′/Delegate ⊓ ¬ P {Finished′} ⊓ ¬ ob1′/Report

A delegate *didn’t* *FINISH* a report.
Analysis of Negation

A delegate finished *no* report.
\[ \bigcup_{i \in \text{Delegate}} \neg \bigcup_{j \in \text{Report}} \text{subj}'/i \cap \text{Finished}' \cap \text{ob1}'/j \]

A delegate *didn’t* finish a report.
\[ \bigcup_{i \in \text{Delegate}} \bigcup_{j \in \text{Report}} \neg (\text{subj}'/i \cap \text{Finished}' \cap \text{ob1}'/j) \]

A delegate *didn’t* finish *any* report.
\[ \bigcup_{i \in \text{Delegate}} \neg \bigcup_{j \in \text{Report}} \text{subj}'/i \cap \text{Finished}' \cap \text{ob1}'/j \]

A delegate *didn’t* *FINISH* a report.
A delegate finished no report.
subj′/ PDelegate △ P {Finished′} △ ¬ ob1′/ PReport

A delegate didn’t finish a report.
subj′/ PDelegate △ ¬P {Finished′} △ ob1′/ PReport

A delegate didn’t finish any report.
subj′/ PDelegate △ ¬P {Finished′} △ ¬ ob1′/ PReport

A delegate didn’t FINISH a report.
... △ (action′/ PAction ⊗ ¬ action′/ {finished}) △ ...
Many British delegates obtained interesting results from the survey.

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

Many delegates obtained interesting results from the survey.

Many \( c = \mathcal{G}_N c \) \hspace{1cm} \text{or} \hspace{1cm} Many \( c = \mathcal{G}_{\alpha|c|} c \)
Many British delegates obtained interesting results from the survey.

Many delegates obtained interesting results from the survey.

Many $c = G_N c \quad \text{or} \quad \text{Many } c = G_{\alpha|c|} c$

Most $c = G_{\alpha|c|} c \quad \text{where } \alpha > 0.5$
Many British delegates obtained interesting results from the survey.

Many delegates obtained interesting results from the survey.

Many $c = G^N_N c$ \quad or \quad Many $c = G^\alpha_{\alpha|c|} c$

Most $c = G^\alpha_{\alpha|c|} c$ \quad where $\alpha > 0.5$

Few $c = \neg(\text{Many } c)$
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- Copula Clauses

  Existence and Subject Relative Clauses

Conclusions
A Swede won a Nobel prize.

Every Swede is a Scandinavian.

A Scandinavian won a Nobel prize.
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▶ Existence and Subject Relative Clauses

Conclusions
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
\(\mathcal{P}\ \{\text{Became}'\} \sqcap \text{ob1}'/\mathcal{P}\ \text{WGT}\)
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

subj’ / (P \{Became’\} □ ob1’/ P WGT)
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

\( \overline{\text{subj}'} / (P \{\text{Became}'\} \sqcap \text{ob1}' / P \text{ WGT}) \)

(a) \( \overline{\text{subj}'} / \text{subj}' / c = c \)  \quad (b) \( d \Rightarrow \text{subj}' / \overline{\text{subj}'} / d \)
Existence and Subject Relative Clauses

An Italian became the world’s greatest tenor.

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

\[
\text{subj}' / \ (\mathcal{P} \text{ Italian} \sqcap (\text{subj}' / (\mathcal{P} \{\text{Became}'\} \sqcap \text{ob1}' / \mathcal{P} \text{WGT})))) \sqcap \mathcal{P} \{\text{Be}'\}
\]

\[
(a) \quad \text{subj}' / \text{subj}' / c = c \quad \quad \quad (b) \quad d \implies \text{subj}' / \text{subj}' / d
\]
Existence and Subject Relative Clauses

An Italian became the world’s greatest tenor.

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

\[
\text{subj}'/ (\text{subj}'/ \text{subj}'/ \mathcal{P}\text{Italian} \sqcap \\
(\text{subj}'/ (\mathcal{P} \{\text{Became}'\} \sqcap \text{ob1}'/ \mathcal{P} \text{WGT}))) \sqcap \mathcal{P} \{\text{Be}'\}
\]

\[(a) \quad \text{subj}'/ \text{subj}'/ c = c \quad \quad (b) \quad d \implies \text{subj}'/ \text{subj}'/ d\]
Existence and Subject Relative Clauses

An Italian became the world’s greatest tenor.

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

\[ \text{subj}'/ \text{subj}'/ (\text{subj}'/ \mathcal{P} \text{Italian} \sqcap \mathcal{P} \{ \text{Became}' \} \sqcap \text{ob1}'/ \mathcal{P} \text{WGT}) \]
\[ \sqcap \mathcal{P} \{ \text{Be}' \} \]

(a) \[ \text{subj}'/ \text{subj}'/ c = c \]
(b) \[ d \Rightarrow \text{subj}'/ \text{subj}'/ d \]
Existence and Subject Relative Clauses

An Italian became the world’s greatest tenor.
\[ \text{subj}'/ \mathcal{P}\text{Italian} \sqcap \mathcal{P}\{\text{Became}'\} \sqcap \text{ob1}'/ \mathcal{P}\text{WGT} \]

An Italian who became the world’s greatest tenor existed.
\[ \text{subj}'/ \overline{\text{subj}}'/ (\text{subj}'/ \mathcal{P}\text{Italian} \sqcap \mathcal{P}\{\text{Became}'\} \sqcap \text{ob1}'/ \mathcal{P}\text{WGT}) \sqcap \mathcal{P}\{\text{Be}'\} \]

(a) \[ \overline{\text{subj}}'/ \text{subj}'/ c = c \quad (b) \quad d \rightarrow \overline{\text{subj}}'/ \overline{\text{subj}}'/ d \]
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▶ Conclusions
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