Textual Entailment
Evolution and Application

Milen Kouylekov
Outline

- What is Textual Entailment?
- Distance Based Approach to Textual Entailment
- Entailment Based approach for Relation Extraction
Language Variability

The same information can be expressed with different ways (e.g. words and syntactic constructs)

Example:

- Ivan Kostov came in power in 1997.
- Ivan Kostov was prime-minister of Bulgaria from 1997 to 2001.
- Ivan Kostov stepped in as prime-minister 6 months after the December 1996 riots in Bulgaria.

Pervasive problem in the area of Natural Language Processing
Examples

● **Lexical variability:**
  Squadra Azzura won the World Cup.

● **Semantic Variability:**
  Italy became world champion for the fourth time.

● **Syntactic & Semantic Variability:**
  The World Cup final was won by Italy.
Paraphrasing

Definition: pairs of units with approximate conceptual equivalence.

Test: substituted for one another in many contexts.

Example:

● Yahoo bought Overture.
● Yahoo purchased Overture.
● Yahoo pay for Overture.
● Yahoo completed acquisition of Overture.

Does not provide a complete model of the problem of language variability:

● Template: X owned Y
● Sentence: Datel corp. sold today DT Communications to Microsoft.

Research Areas

The following areas have something in common:

- Information Retrieval
- Question Answering
- Information Extraction
- Summarization
- ...

...
Textual Entailment

An Entailment Relation holds between two text fragments (i.e. text T and hypothesis H) when the meaning of H, as interpreted in the context of T, can be inferred from the meaning of T.

- **Directional** - an expression entails the other, while the opposite may not.
- **Probabilistic** - the relation is not deterministic.

Example:

T - "For the first time in history, the players are investing their own money to ensure the future of the game,” Atlanta Braves pitcher Tom Glavine said.

H - Tom Glavine plays for the Atlanta Braves.

Entailment Rules

- Entailment Rules play a crucial role in textual entailment.
- An entailment rule consists of an entailing template (left hand side RHS) and an entailed template (right hand side RHS), which share the same variable scope.
- In order to apply an entailment rule, an appropriate prior or contextual (posterior) probability has to be assigned.

\[
X \leftarrow \text{sell} \rightarrow Y \Rightarrow X \leftarrow \text{own} \rightarrow Y
\]

\[
Y \leftarrow X \rightarrow \text{pitcher} \Rightarrow X \leftarrow \text{play} \rightarrow Y
\]
Recognizing Textual Entailment

- RTE takes as input a T-H pair and consists in automatically determining whether an entailment relation* between T and H holds or not.
- Evaluated in 9 monolingual (8 English and 1 Italian) evaluation campaigns and 2 cross-language campaigns (CLTE)
RTE 1, 2 & Evalita

● One Text and One Hypothesis
● 2 Semantic Relations Between Texts
  ○ Entailment (YES)
  ○ No Entailment (NO)

<pair value="TRUE" task="CD">
  <t>
    Recreational marijuana smokers are no more likely to develop oral cancer than nonusers.
  </t>
  <h>
    Smoking marijuana does not increase the risk of developing oral cancer.
  </h>
</pair>
RTE 3, 4 & 5

- One Text and One Hypothesis
- 3 Relations
  - Entailment
  - Contradiction
  - Unknown

<pair value="CONTRADICTION" task="CD">
  <t>
    Yahoo both Overture.
  </t>
  <h>
    Yahoo sold Overture.
  </h>
</pair>
RTE 5 & 6

- One Hypothesis Multiple Texts
- 2 Semantic Relations between texts (YES|NO)
RTE 8

- One Text and One Hypothesis
- 5 Semantic Relations (Student Responses)
  - Correct
  - Partially Correct
  - Contradictory
  - Irrelevant
  - Non Domain
Cross Language Textual Entailment

- One Text and One Hypothesis
- 4 Relations (Content Synchronization)
  - Bi-Directional
  - Forward
  - Backward
  - No Entailment
Edit Distance Based Approach

We assume that the distance between T and H is a characteristic that separates the positive pairs from the negative pairs.

- It exists a function, with range from 0 to K, that calculates an entailment score of a T-H pair based on the edit distance between T and H.
- If T and H are the same, then T entails H.
- If T and H are completely different then, T does not entail H.
- It exists a distance boundary (threshold) S, 0 < S < K, that separates the positive from the negative examples.
Edit Operations

We assume that the distance between $T$ and $H$ is computed as the cost of the editing operations on text fragments that transform $T$ into $H$.

Edit Operation - An operation that converts a text fragment $A$ into another text fragment $B$ ($A \rightarrow B$) with a certain cost $\gamma(A \rightarrow B)$.

- Insertion $\Lambda \rightarrow A$: Inserts a text fragment $A$ from $H$ in $T$.
- Deletion $A \rightarrow \Lambda$: Removes a text fragment $A$ from $T$.
- Substitution $A \rightarrow B$: Replaces a text fragment $A$ from $T$ with a text fragment $B$ from $H$. 
Algorithms

- Token Edit Distance (Levenshtein Distance on Words)
- Tree Edit Distance (Dependency Trees)
  - Kouylekov & Magnini Tree Edit Distance for Recognizing Textual Entailment
- Similarity Algorithms
  - Word Overlap
  - Longest Common Subsequence
  - Rouge
Substitution - Matching

- Central Part of the approach
- Employs Entailment Rules
- Source:
  - WordNet
  - Paraphrasing Resources
  - Similarity Databases
  - Ontologies
- Rules extracted using Web Crawling
  - L. Romano et. al. Investigating a Generic Paraphrase-Based Approach for Relation Extraction
Insertion & Deletion (Weight)

- **Linguistically Motivated Rules**
  - Negation

- **Approximations**
  - Inverse Document Frequency

- **Learning**
  - Genetic Algorithms
  - Mehdad & Magnini (2009) - Optimizing textual entailment recognition using particle swarm optimization
How this thing work for RTE

- **2 Relations**
  - Calculate a threshold that separates the positive from the negative

- **3 Relations**
  - Calculate 2 thresholds by grouping 2 similar relations and then separating

- **Multiple Relations**
  - Use Learning Algorithm
Generalized Architecture
Open Source

EDITS is available at SourceForge
http://edits.sf.net


Kouylekov et.al. Is it Worth Submitting this Run? Assess your RTE System with a Good Sparring Partner. TextInfer (EMNLP 2011)
Qall-Me Project

● Objectives
  ○ “design and implementation of a semantic based answer extraction Web Service […] extract short answers […] evaluate their reliability […] return context sensitive answer representations”
Recast our QA problem as a TE recognition problem where:
- $t$ is the input question
- $h$ is a textual pattern stored in a pattern repository
- Textual patterns are associated to instructions for answer retrieval (in our case SPARQL queries to a database)

Task: given a question ($Q$), check for the existence of entailment relations between $Q$ and a set of textual patterns ($p_1, \ldots, p_n$), stored in a pattern repository $P$, which describe the relations of interest in a certain domain.
QALL-ME TE-based Approach

Given:
A question $Q_i$
A repository $P$ of patterns $p_1, \ldots, p_n$ associated to SPARQL queries $q_{p_1}, \ldots, q_{p_n}$

Step1: If Exists pattern $p_j$ in $P$

IF $Q_i$ entails $p_j$
THEN collect $p_j/q_{p_j}$
ELSE nil
RETURN entailed $p/q$ pairs

Step2: **COMBINE** the collected queries in a single query to the DB
<table>
<thead>
<tr>
<th>Input question</th>
<th>Pattern repository</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q: “Where is cinema Astra located?”</td>
<td></td>
</tr>
<tr>
<td>P₁: What is the telephone number of Cinema:X?</td>
<td>P₁SPARQL</td>
</tr>
<tr>
<td>P₂: Who is the director of Movie:X?</td>
<td>P₂SPARQL</td>
</tr>
<tr>
<td>P₃: What is the ticket price of Cinema:X?</td>
<td>P₃SPARQL</td>
</tr>
<tr>
<td>P₄: Give me the address of Cinema:X.</td>
<td>P₄SPARQL</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Pₙ</td>
<td>PₙSPARQL</td>
</tr>
</tbody>
</table>
Q: "Where is cinema Astra located?"

P₁: What is the telephone number of Cinema:X?

P₂: Who is the director of Movie:X?

P₃: What is the ticket price of Cinema:X?

P₄: Give me the address of Cinema:X.

...  

Pₙ: ...
Input question

Q: “Where is cinema Astra located?”

Pattern repository

<table>
<thead>
<tr>
<th>Pattern</th>
<th>SPARQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$: What is the telephone number of *Cinema:*X?</td>
<td>$P_1$SPARQL</td>
</tr>
<tr>
<td>$P_2$: Who is the director of *Movie:*X?</td>
<td>$P_2$SPARQL</td>
</tr>
<tr>
<td>$P_3$: What is the ticket price of *Cinema:*X?</td>
<td>$P_3$SPARQL</td>
</tr>
<tr>
<td>$P_4$: Give me the address of *Cinema:*X.</td>
<td>$P_4$SPARQL</td>
</tr>
<tr>
<td>$\ldots$</td>
<td>$\ldots$</td>
</tr>
<tr>
<td>$P_n$</td>
<td>$P_n$SPARQL</td>
</tr>
</tbody>
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Entailment engine

$Q \Rightarrow P_4$
Entailment-based NLI2DB

**Input question**

Q: “Where is cinema Astra located?”

**Pattern repository**

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<td>P₄SPARQL</td>
</tr>
<tr>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Pₙ</td>
<td>PₙSPARQL</td>
</tr>
</tbody>
</table>

**Entailment engine**

```
SELECT ?address
WHERE { ?cinema rdf:type tourism:Cinema
    ?cinema tourism:name "Astra".
    ?cinema tourism:hasPostalAddress ?addr.
    ?addr tourism:street ?address }
```
Q: “Where is cinema Astra located?”

A: Corso Buonarroti, 16 - Trento
Entailment-based NLI2DB

Q: “What’s the address of Astra?”

SELECT ?address
WHERE { ?cinema rdf:type tourism:Cinema
?cinema tourism:name “Astra”.
?cinema tourism:hasPostalAddress ?addr.
?addr tourism:street ?address }

A: Corso Buonarroti, 16 - Trento
Q: “Where can I find a cinema in the city centre?”

Entailment engine

Pattern repository

| P₁: What is the telephone number of Cinema:X? | P₁ SPARQL |
| P₂: Who is the director of Movie:X? | P₂ SPARQL |
| P₃: What is the ticket price of Cinema:X? | P₃ SPARQL |
| P₄: Give me the address of Cinema:X. | P₄ SPARQL |
| ... | ... |
| Pₙ | Pₙ SPARQL |

SELECT ?address
WHERE { ?cinema rdf:type tourism:Cinema
?cinema tourism:name “Astra”.
?cinema tourism:hasPostalAddress ?addr.
?addr tourism:street ?address }

A: Corso Buonarroti, 16 - Trento
Entailment-based NLI2DB

Q: “I want to see a movie at Astra. Where is it?”

Pattern repository

| P₁: What is the telephone number of Cinema:X? | P₁ SPARQL |
| P₂: Who is the director of Movie:X? | P₂ SPARQL |
| P₃: What is the ticket price of Cinema:X? | P₃ SPARQL |
| P₄: Give me the address of Cinema:X. | P₄ SPARQL |

... 
Pₙ

SELECT ?address
WHERE { ?cinema rdf:type tourism:Cinema
?cinema tourism:name "Astra".
?cinema tourism:hasPostalAddress ?addr.
?addr tourism:street ?address }

A: Corso Buonarroti, 16 - Trento
Advantages of the proposed framework

- Simplicity
  - Linguistic variations are handled at textual level
    - Process independent from the DB schema: no need of explicit mapping between linguistic expressions and the DB content
    - Reduced manual effort

- Flexibility
  - A variety TE recognition approach/algorithm can be used and experimented
    - From simpler BOW approaches to more complex techniques based on deep syntactic analysis
Minimal Relational Patterns

- **Focus:** question decomposition into *basic relations*
  - Entailment checking between *questions* and *Minimal Relational Patterns* *(def: “minimal text portions expressing a relation between two entities”)*

- **Motivation:** mapping questions to MRPs enables a more effective treatment of *complex inputs* (i.e. those involving many relations)

> “On Saturday, *where* can I see *in the city centre* a *comedy starring Ben Stiller*?”

- **Techniques:** distance-based TE recognition
  - *Levenshtein Distance*: estimate the costs of transforming (through words *insertion*, *deletion*, or *substitution*) a question \( Q \) into a pattern \( P \)
Q: Come si intitola il film di stasera all’Astra di Trento?
Q: Come si *intitola* il *film* di stasera all’Astra di Trento?

RELATION ENTAILED MRP SPARQL

HasTitle(Movie,Title) P1 Dimmi il *titolo* di [MOVIE] Q1
Q: Come si intitola il film di stasera all’Astra di Trento?

REATION ENTAILED MRP SPARQL
HasTitle(Movie,Title) P1 Dimmi il titolo di [MOVIE] Q1
HasMovie(Cinema,Movie) P2 [MOVIE] al cinema [CINEMA] Q2
Q: Come si intitola il film di stasera all’Astra di Trento?

RELATION ENTAILED MRP SPARQL

HasTitle(Movie,Title) P1 Dimmi il titolo di [MOVIE] Q1
HasMovie(Cinema,Movie) P2 [MOVIE] al cinema [CINEMA] Q2
HasDate(Movie,Date) P3 film in programma [T-EXP] Q3
Q: Come si intitola il film di stasera all’Astra di Trento?

RELATION ENTAILED MRP SPARQL
HasTitle(Movie,Title) P1 Dimmi il titolo di [MOVIE] Q1
HasMovie(Cinema,Movie) P2 [MOVIE] al cinema [CINEMA] Q2
HasDate(Movie,Date) P3 film in programma [T-EXP] Q3
IsInCity(Cinema,City) P4 [CINEMA] di [LOCATION] Q4
Q: Come si intitola il film di stasera all’Astra di Trento?

RELATION ENTAILED MRP SPARQL

HasTitle(Movie,Title) P1 Dimmi il titolo di [MOVIE] Q1
HasMovie(Cinema,Movie) P2 [MOVIE] al cinema [CINEMA] Q2
HasDate(Movie,Date) P3 film in programma [T-EXP] Q3
IsInCity(Cinema,City) P4 [CINEMA] di [LOCATION] Q4

Combined SPARQL query to the DB

A: Ratatouille
What to do by hand?

- **Minimal manual effort**

1. Collect domain-specific questions (QALL-ME benchmark)

2. To each question $Q_i$, associate all the ontology relations it expresses $R_1, \ldots, R_n$

3. Split $[Q,R]$ pairs into training and test set

4. For each relation $R_x$, build a cluster $C_{Rx}$ of positive examples expressing $R_x$

5. Extract relational patterns $P$ from training questions (Pattern Extraction using Genetic Algorithm)
   - Kouylekov & Negri Detecting Expected Answer Relations through Textual Entailment.

6. Train a TE engine over $[Q,P]$ pairs, both on positive and negative examples

7. Use test $[Q,R]$ pairs to evaluate the entailment engine
Evaluation

- F-Measure: .72
- User Centric Evaluation:
  - The question got a correct answer?
  - Four types:
    - Recognized all relations correctly (178)
    - Recognized some of relations (230)
    - Recognized some correctly some wrong (29)
    - Recognized only wrong (51)
Thanks

DEAL WITH IT