Reasoning about Quantities in Natural Language

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2: Talk Outline

- Introduction
- Representation for Quantities
- Quantity Entailment
- Math Word Problems
Part I

Introduction
A bomb in Hebrew University cafeteria killed five Americans and four Israelis.

A bombing at Hebrew University in Jerusalem killed nine people, including five Americans.
Ryan has **72 marbles** and **17 blocks**. If he shares the marbles among **9 friends**, how many marbles does each friend get?

Each friend gets $\frac{72}{9} = 8$ marbles. The number of blocks is irrelevant.
Part II

Representation for Quantities
Quantity Value Representation (QVR)

Every quantity is represented as a triple ...

(Value, Unit, Change)

- Numeric range or set of values
- Noun phrase that describes what the value is associated with
- Whether parameter is changing

"increased 10%" \equiv (10, \text{percentage}, \text{true})
Quantity Value Representation (QVR)

Every quantity is represented as a triple ...

(Value, Unit, Change)

Numeric range or set of values

Whether parameter is changing

Noun phrase that describes what the value is associated with

“increased 10%” ≡ (10, percentage, true)
6: Extraction of QVR

- Natural language text
- Segmentation (BIO tagger)
- Normalizer (Rule based)
- Quantity phrases
- QVRs
6: Extraction of QVR

Natural language text → Segmentation (BIO tagger) → Normalizer (Rule based) → Quantity phrases → QVRs
Around six and a half hours later, Mr. Armstrong opened the landing craft’s hatch.

**Dataset**

600 sentences of newswire and 384 sentences from RTE containing quantity information.

| Method                  | Precision | Recall | F1   |
|-------------------------|-----------|--------|------|
| Semi-CRF                | 75.6%     | 77.7%  | 76.6%|
| Bank of classifiers     | 80.3%     | 79.3%  | 79.8%|

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Around six and a half hours later \((\approx 6.5, \text{hour, true})\), Mr. Armstrong opened the landing craft’s hatch.

Normalization

- Rule driven module
- Often units do not appear adjacent to numeric entities, hence might not be mentioned in segmented phrase.
The number of member nations was 80 in 2000, and then it increased to 95.

Unit for “95”? 
- Coreference Resolution 
- Semantic Role Labeling
The number of member nations was 80 in 2000, and then it increased to 95.

Unit for “95”? 
- Coreference Resolution
- Semantic Role Labeling
The number of member nations was 80 in 2000, and then [it] increased to [95].

Unit for “95”?  
- Coreference Resolution  
- Semantic Role Labeling
Part III

Quantity Entailment
**T**: A bomb in Hebrew University cafeteria killed **five Americans** and **four Israelis**.

**H**: A bombing at Hebrew University in Jerusalem killed **nine people**, including **five Americans**.

**Question**

Given a statement **T** and a quantity **q** in **H**, does it entail from some quantity in **T**?

“**five Americans and four Israelis**” → “**nine people**”

For inexact match, we assumed upward monotonicity to be true.
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10: Quantity Entailment

\[ T : \text{A bomb in Hebrew University cafeteria killed five Americans and four Israelis.} \]

\[ H : \text{A bombing at Hebrew University in Jerusalem killed nine people, including five Americans.} \]

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**Question**

Given a statement **T** and a quantity \( q \) in **H**, does it entail from some quantity in **T**?

“five Americans and four Israelis” \( \rightarrow \) “nine people”

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Baseline: String matching based algorithm
Part IV

Math Word Problems
Math word problems from standard 1 to 6.

Conditions

- Mentions two or three quantities.
- Answer is obtained by
  - Choosing two quantities
  - Applying one of four basic operations (add, subtract, multiply, divide) on them.
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**Problem text and extracted quantities**

**Number of blocks irrelevant**

**Operation classifier**

**Relevant operation**: division

**Order classifier**

72/9 and not 9/72
Ryan has 72 marbles and 17 blocks. If he shares the marbles among 9 friends, how many marbles does each friend get?

Problem text and extracted quantities

Operation classifier

Relevant operation: division

Number of blocks irrelevant

Quantity Pair classifier

72/9 and not 9/72
Ryan has **72 marbles** and **17 blocks**. If he shares the marbles among **9 friends**, how many marbles does each friend get?

Problem text and extracted quantities

- **Operation classifier**: Relevant operation: division
- **Number of blocks irrelevant**: Quantity Pair classifier
- **Order classifier**: 72/9 and not 9/72

Relevant operation: division
14: Result

Accuracy

- Correct Answer
- Order Classifier
- Operation Classifier
- Quantity Pair Classifier

Accuracy
- Analyze the role of predicates in more general quantitative reasoning.
- Deeper understanding of math word problems.
Thank You