Sentence Annotation: Semantic Role Labeling

Question Answering
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Automatic Labeling of Semantic Roles
Agenda

• Frame Semantics

• Goals

• Approach

• Discussion
What are Semantic Roles?
Frame Semantics

- Linguistic theory
  - Knowledge of context → word can be (partially) understood

Jim flew his plane to Texas.

Alice destroys the item with a plane.
Frame Semantics

- Linguistic theory
  - Knowledge of context → word can be (partially) understood

Jim flew his **plane** to Texas.

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- Linguistic theory
  - Knowledge of context → word can be (partially) understood

Jim flew his [plane] to Texas.

Alice destroys the item with a [plane].
Frame Semantics – Semantic Frames

• Semantic Frame: collection of facts that specify “characteristic features, attributes, and functions of a denotatum, and its characteristic interactions with things necessarily or typically associated with it” (Keith Alan, Natural Language Semantics)

• Target words invoke a semantic frame

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Frame Semantics – Semantic Roles

- Semantic Role: defined part of a Semantic frame
- Can be assigned to constituents of a sentence

Jim flew his plane to Texas.  
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Operate_vehicle  
Destroying
• Semantic Role: defined part of a Semantic frame

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Jim flew his plane to Texas.  
Driver  Vehicle  Goal

Operator_vehicle

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Jim flew his plane to Texas.

Driver Vehicle Goal

Alice destroys the item with a plane.

Destroyer Undergoer Instrument

Operate_vehicle

Destroying
Frame Semantics - Range

- Wide range possible

Abstract
- Agent
- Patient
- Experiencer
- Source
- ...

Domain Specific
- Buyer
- Depart_Time
- Dest_Airport
- Winning_Team
- ...

QA – Sentence Annotation: Semantic Role Labeling | Sebastian Oergel | 21.11.2011
Frame Semantics – FrameNet

- Dictionary based on semantic frames
  - Uses British National Corpus
- Contains large set of:
  - Example sentences
  - Target words (“Lexical Units”)
  - Semantic frames (grouped in domains)
  - Associated roles (frame elements)
- Manually annotated

https://framenet.icsi.berkeley.edu
Frame Semantics – FrameNet

• Example

Domain: Communication
Frame: Conversation
Frame Elements: Protagonist–1, Protagonist–2, Protagonists, Topic, Medium

Frame: Questioning
Frame Elements: Speaker, Addressee, Message, Topic, Medium

Frame: Statement
Frame Elements: Speaker, Addressee, Message, Topic, Medium

Domain: Cognition
Frame: Judgment
Frame Elements: Judge, Evaluate, Reason, Role

Frame: Categorization
Frame Elements: Cognizer, Item, Category, Criterion

Example frames and their elements:
- Questioning: blame–v, admire–v, appreciate–v
- Statement: fault–n, dispute–n, disapprove–v

HPI Hasso Plattner Institut
Goals
Goals – Usage in QA

• How can semantic roles help in QA?

• ➔ analyze question ➔ analyze possible answer sentences ➔ find equalities between frames
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Q: Who invented the first computer mouse?
Goals – Usage in QA

- How can semantic roles help in QA?

- Analyze question
  - Analyze possible answer sentences
  - Find equalities between frames

Q: Who invented the first computer mouse?

[...] The trackball was invented by Tom Cranston, Fred Longstaff and Kenyon Taylor working on the Royal Canadian Navy's DATAR project in 1952. Independently, Douglas Engelbart at the Stanford Research Institute invented the first computer mouse in 1963 [...]

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Automatic Labeling of Semantic Roles

[... ] The trackball was invented by Tom Cranston, Fred Longstaff and Kenyon Taylor working on the Royal Canadian Navy's DATAR project in 1952. Independently, Douglas Engelbart at the Stanford Research Institute invented the first computer mouse in 1963 [... ]
Approach
Approach – Basic Idea

- Statistical classifier
  - Assigns roles based on probabilities
  - Probabilities calculated / derived from features

- FrameNet data
  - 10% for testing, 10% for tuning, 80% for training

- Given data:
  - Sentence / clause
  - Target word
  - Frame
  - (role boundaries)
• “Collins” Parser for generating a parse tree
• Used for the derivation of some features
Approach – Features

- “Collins” Parser for generating a parse tree
- Used for the derivation of some features
Approach – Features – Phrase type

[S
  NP
    NNP
      Farrell
      Theme
  VP
    VBD
      approached
      target
    NP
      PRP
      him
      Goal
  PP
    IN
    NP
      from
      Source
    NN
      behind]
Approach – Features – Phrase type

- “Farrell” $\rightarrow$ NP
- “him” $\rightarrow$ NP
- “from behind” $\rightarrow$ PP
Approach – Features – Governing Category

[Diagram showing a tree structure with nodes labeled as follows:
- S (Sentence)
- NP
- NNP
- VBD
- NP
- PRP
- PP
- IN
- NP
- NN

Words and categories:
- Farrell
- approached
- him
- from
- behind

Categories:
- Theme
- target
- Goal
- Source]
• “Farrell” → S
• “him” → VP
• “from behind” → nothing
Approach – Features – Parse Tree Path

- **S**
  - **NP**
    - **NNP** – Farrell
      - Theme
  - **VP**
    - **VBD** – approached
      - target
    - **NP**
      - **PRP** – him
      - Goal
    - **PP**
      - **IN** – from
      - **NP**
        - **NN** – behind
      - Source
Approach – Features – Parse Tree Path

- “Farrell” → VBD↑VP↑S↓NP
- ...
- ...

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Approach – Features – Position

```
( S
  (NP (NNP Farrell))
  (VP
    (VBD approached)
    (NP (PRP him))
    (PP
      (IN from)
      (NP (NN behind))))
```

- **Theme**: Farrell
- **Target**: approached
- **Goal**: him
- **Source**: from behind
"Farrell" → before
"him" → behind
"from behind" → behind
Approach – Features – Voice

The diagram illustrates a tree structure representing a sentence with labeled semantic roles. The sentence is: "Farrell approached him from behind.

- **NP**: Farrell
- **NNP**: Theme
- **VBD**: approached
- **PRP**: target
- **NP**: him
- **PP**: from
- **NP**: behind
- **IN**: Source

The roles are:

- **Theme**: Farrell
- **Target**: approached
- **Goal**: him
- **Source**: from behind
• “Farrell” → active
• “him” → active
• “from behind” → active
Approach – Features – Head Word

The diagram represents a sentence with labeled parts of speech and semantic roles. The sentence is:

Farrell approached him from behind

- **Farrell** (NNP): Theme
- **approached** (VBD): Goal
- **him** (PRP): Goal
- **from** (IN): Source
- **behind** (NN): Source
• “Farrell” → “Farrell”
• “him” → “him”
• “from behind” → “behind”
Approach – Probability Estimation

- Probabilities calculated based on features

- Probability:

- Calculation:
Approach – Probability Estimation

• Probabilities calculated based on features

• Probability:  \( P(r \mid h, pt, gov, position, voice, t) \)

• Calculation:
Approach – Probability Estimation

- Probabilities calculated based on features

- Probability: \( P(r \mid h, pt, gov, position, voice, t) \)

- Calculation:

\[
P(r \mid h, pt, gov, position, voice, t) = \frac{\#(r, h, pt, gov, position, voice, t)}{\#(h, pt, gov, position, voice, t)}
\]
Approach – Probability Estimation

\[ P(r \mid h, pt, gov, position, voice, t) \]

- Example:
  - How often occurs ("Farrell", NP, S, before, active,"approached")?
Approach – Probability Estimation

\[ P(r \mid h, pt, gov, position, voice, t) \]

- Example:
  - How often occurs ("Farrell", NP, S, before, active,"approached")?
  - 436 times
Approach – Probability Estimation

\[ P(r \mid h, pt, gov, position, voice, t) \]

- Example:
  - How often occurs (“Farrell”, NP, S, before, active,”approached”)?
    - 436 times
  - How often does this combination have the role “Theme”?
    - 387 times
Approach – Probability Estimation

\[ P(r \mid h, pt, gov, position, voice, t) \]

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    - 387 times
  - How often does this combination have the role “Vehicle”?
    - 8 times
Approach – Probability Estimation

\[ P(r \mid h, pt, gov, position, voice, t) \]

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\[ P("Theme" \mid "Farrell", NP, S, before, active,"approached") \approx 89\% \]
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\[ P("Vehicle" \mid "Farrell", NP, S, before, active,"approached") \approx 2\% \]
Approach – Probability Estimation

\[ P(r \mid h, pt, gov, position, voice, t) \]

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• Problem: features not always available (0 occurrences)
  • Esp. head word: very specific
• \( P(r \mid h, pt, gov, position, voice, t) \) might be too strict
Approach – Probability Estimation

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- Solution:
  - Subset of probabilities
  - Different combinations
Approach – Probability Estimation

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<th>Accuracy</th>
<th>Performance</th>
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<td>( P(r \mid t) )</td>
<td>100.0%</td>
<td>40.9%</td>
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<tr>
<td>( P(r \mid pt, t) )</td>
<td>92.5</td>
<td>60.1</td>
<td>55.6</td>
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<td>92.0</td>
<td>66.6</td>
<td>61.3</td>
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<td>98.8</td>
<td>57.1</td>
<td>56.4</td>
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Approach – Probability Estimation

- Idea: combine distributions
  - Linear interpolation

\[
P(r \mid \text{constituent}) = \lambda_1 P(r \mid t) + \lambda_2 P(r \mid pt, t) \\
+ \lambda_3 P(r \mid pt, gov, t) + \lambda_4 P(r \mid pt, position, voice) \\
+ \lambda_5 P(r \mid pt, position, voice, t) + \lambda_6 P(r \mid h) \\
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+ \lambda_7 P(r \mid h, t) + \lambda_8 P(r \mid h, pt, t)
\]

- 79.5% performance
Approach – Probability Estimation

• Idea: combine distributions
  • “Backoff”
Approach – Probability Estimation

- Idea: combine distributions
  - "Backoff"

- 80.4% performance
Optional: Boundaries

- Additional step before the automatic labeling
- Similar techniques as described before
  - Here: no differentiation among multiple roles → is parse constituent a role or not?
- Threshold for probability required
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    VBD approached
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      PRP him
    PP
      IN from
      NP behind
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For different recognition thresholds
Discussion

• With given boundaries → relatively high performance
  • Interpolation of different probability distributions combinations makes sense
• Without boundaries → much lower performance
• Still some tasks open
  • Mostly disambiguation
Discussion

• With given boundaries $\rightarrow$ relatively high performance
  • Interpolation of different probability distributions combinations makes sense
• Without boundaries $\rightarrow$ much lower performance
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• Integration into QA system
  • Input: Question + Possible answer sentences ($\rightarrow$ disambiguation for frame required)
  • Connection to FrameNet
References
