Question-Answer Driven Semantic Role Labeling

Using Natural Language to Annotate Natural Language

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EMNLP 2015
Semantic Role Labeling (SRL)

who did what to whom, when and where?
Semantic Role Labeling (SRL)

**Predicate**

They *increased* the rent *drastically* this year

**Role**

**Agent**

**Patent**

**Time**

**Manner**
Semantic Role Labeling (SRL)

They increased the rent drastically this year.

- **Agent**: They
- **Predicate**: increased
- **Argument**: the rent, drastically, this year
- **Role**: Argument
- **Manner**: drastically
- **Time**: this year

- Defining a set of roles can be difficult
- Existing formulations have used different sets
Existing SRL Formulations and Their Frame Inventories

**FrameNet**
1000+ semantic frames,
10,000+ frame elements (roles)

**PropBank**
10,000+ frame files
with predicate-specific roles

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**Frame:** Change_position_on_a_scale
This frame consists of words that indicate the change of an Item’s position on a scale (the Attribute) from a starting point (Initial_value) to an end point (Final_value). The direction (Path) …

**Lexical Units:**
..., reach.v, rise.n, rise.v, rocket.v, shift.n, ...

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**Roleset Id:** rise.01, go up

**Arg1-:** Logical subject, patient, thing rising
**Arg2-EXT:** EXT, amount risen
**Arg3-DIR:** start point
**Arg4-LOC:** end point
**Argm-LOC:** medium

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Unified Verb Index, University of Colorado [http://verbs.colorado.edu/verb-index/](http://verbs.colorado.edu/verb-index/)
PropBank Annotation Guidelines, Bonial et al., 2010
FrameNet II: Extended theory and practice, Ruppenhofer et al., 2006
FrameNet: [https://framenet.icsi.berkeley.edu/](https://framenet.icsi.berkeley.edu/)
This Talk: QA-SRL

• Introduce a new SRL formulation with no frame or role inventory

• Use question-answer pairs to model verbal predicate-argument relations

• Annotated over 3,000 sentences in weeks with non-expert, part-time annotators

• Showed that this data is high-quality and learnable
Our Annotation Scheme

**Given sentence and a verb:**

They *increased* the rent this year.
Our Annotation Scheme

Given sentence and a verb:

They *increased* the rent this year.

Step 1: Ask a question about the verb:

Who increased something?
Our Annotation Scheme

Given sentence and a verb:

They *increased* the rent this year.

**Step 1: Ask a question about the verb:**

Who increased something?

**Step 2: Answer with words in the sentence:**

They
Our Annotation Scheme

Given sentence and a verb:
They *increased* the rent this year.

**Step 1: Ask a question about the verb:**
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They

**Step 3: Repeat, write as many QA pairs as possible ...**
Our Annotation Scheme

Given sentence and a verb:

They *increased* the rent this year.

Step 1: Ask a question about the verb:
Who increased something?

Step 2: Answer with words in the sentence:
They

Step 3: Repeat, write as many QA pairs as possible ...
What is increased? the rent
When is something increased? this year
The rent rose 10% from $3000 to $3300.

Frameset: rise.01, go up

ARG1-: Logical subject, patient, thing rising
ARG2-EXT: EXT, amount risen
ARG3-DIR: start point
ARG4-LOC: end point
Argm-LOC: medium

• Depends on pre-defined frame inventory
• Annotators need to:
  1) Identify the Frameset
  2) Find arguments in the sentence
  3) Assign labels accordingly
• If frame doesn’t exist, create new

The Proposition Bank: An Annotated Corpus of Semantic Roles, Palmer et al., 2005
http://verbs.colorado.edu/propbank/framesets-english/rise-v.html
Our Method: Q/A Pairs for Semantic Relations

The rent rose 10% from $3000 to $3300

Wh-Question

What rose?  
the rent

How much did something rise?  
10%

What did something rise from?  
$3000

What did something rise to?  
$3300
Comparing to Existing SRL Formulations

No Role Inventory!

Question

(Verbal) Predicate

Answer

Predicate

Role

Argument

Question-Answer Driven SRL (QA-SRL)

Large Role Inventory

SRL
Advantages

• Easily explained
• No pre-defined roles, few syntactic assumption
• Can capture implicit arguments
• Generalizable across domains
**Advantages**
- Easily explained
- No pre-defined roles, few syntactic assumption
- Can capture implicit arguments
- Generalizable across domains

**Limitations**
- Only modeling verbs (for now)
- Not annotating verb senses directly
- Can have multiple equivalent questions
Advantages
• Easily explained
• No pre-defined roles, few syntactic assumption
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• Only modeling verbs (for now)
• Not annotating verb senses directly
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Challenges
• What questions to ask?
• Quality - Can we get good Q/A pairs?
• Coverage - Can we get all the Q/A pairs?
Outline

- Motivation and Intuition
- Data Collection and Analysis
- Learning Tasks and Baselines
- Future Work and Conclusion

- Semantic Role Labeling
- Our Method: QA-SRL
- Annotation Task Design
- Dataset Statistics
- Quality Analysis
Question-Answer Driven SRL

Given sentence $s$, target verb $v$

Annotate all possible question-answer pairs $\langle q, a \rangle$
Question-Answer Driven SRL

Given sentence $s$, target verb $v$

Annotate all possible question-answer pairs $<q,a>$

- Question $q$ should start with a **wh-word** and contain the target verb $v$
- Answer $a$ should be a phrase from the sentence $s$. Multiple correct answers are allowed.
Writing Questions

\[ q \in \text{WH} \times \text{AUX} \times \text{SBJ} \times \text{TRG} \times \text{OBJ1} \times \text{PP} \times \text{OBJ2} \]
Writing Questions

\[ q \in \text{WH} \times \text{AUX} \times \text{SBJ} \times \text{TRG} \times \text{OBJ1} \times \text{PP} \times \text{OBJ2} \]

Writing Questions

$q \in \text{WH} \times \text{AUX} \times \text{SBJ} \times \text{TRG} \times \text{OBJ1} \times \text{PP} \times \text{OBJ2}$

**WH:** Who, What, When, Where, Why, How, How much

**AUX:** Auxiliary verbs, including negations. i.e. is, might, won’t
Writing Questions

\[q \in WH \times AUX \times SBJ \times TRG \times OBJ1 \times PP \times OBJ2\]

**WH:** Who, What, When, Where, Why, How, How much

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Writing Questions

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Writing Questions

\[ q \in \text{WH} \times \text{AUX} \times \text{SBJ} \times \text{TRG} \times \text{OBJ1} \times \text{PP} \times \text{OBJ2} \]


**AUX**: Auxiliary verbs, including negations. i.e. is, might, won’t

**SBJ, OBJ1, OBJ2**: someone, something, do something, etc.

**TRG**: Target verb, including inflected forms.

**PP**: Preposition. i.e. to, for, from, about, etc.
# Writing Questions

<table>
<thead>
<tr>
<th>WH*</th>
<th>AUX</th>
<th>SBJ</th>
<th>TRG*</th>
<th>OBJ1</th>
<th>PP</th>
<th>OBJ2</th>
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</thead>
<tbody>
<tr>
<td>Who</td>
<td></td>
<td></td>
<td>built</td>
<td>something</td>
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<tr>
<td>What</td>
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<td>someone</td>
<td></td>
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<td></td>
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<td>said</td>
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<td></td>
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<td>was</td>
<td>someone</td>
<td>expected</td>
<td></td>
<td>to</td>
<td>do something</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where</td>
<td>might</td>
<td>something</td>
<td>rise</td>
<td></td>
<td>from</td>
<td></td>
</tr>
</tbody>
</table>
Revenue **rose** 33% to $378.1 million from $283.8 million.

But Western Union has said it must **lower** the interest rate on its debt to regain full financial health.
Revenue **rose** 33% to $378.1 million from $283.8 million.

But Western Union has said it must **lower** the interest rate on its debt to regain full financial health.
Dataset Statistics

- **newswire (PropBank)**
  - Sentences: 1,241
  - Verbs: 3,336
  - QA Pairs: 8,109

- **Wikipedia**
  - Sentences: 8,109
  - Verbs: 3,336
  - QA Pairs: 1,241
Dataset Statistics

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<tr>
<th></th>
<th>newswire (PropBank)</th>
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<tr>
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<tr>
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<tr>
<td>QA Pairs</td>
<td>3,336</td>
<td>8,109</td>
</tr>
</tbody>
</table>
Cost and Speed

- Part-time freelancers from upwork.com (hourly rate: $10)
- ~2h screening process for native English proficiency
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Cost and Speed

- Part-time freelancers from upwork.com (hourly rate: $10)
- ~2h screening process for native English proficiency
**Sentence:** Clad in his trademark black velvet suit, the soft-spoken clarinetist announced that . . . and that it was his mother’s birthday, so he was going to **play** her favorite tune from the record.

<table>
<thead>
<tr>
<th>QA-SRL</th>
<th>PropBank (CoNLL-2009)</th>
</tr>
</thead>
</table>
| Who would play something?  
the soft-spoken clarinetist / **he** | ARG0: **he** |
| What would be played?  
her favorite **tune** from the record | ARG1: **tune** |
| When would someone play something?  
his mother’s birthday | / |
**Sample Annotation**

**Sentence:** Clad in his trademark black velvet suit, the soft-spoken clarinetist announced that . . . and that it was his mother’s birthday, so he was going to **play** her favorite tune from the record.

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<thead>
<tr>
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<th>PropBank (CoNLL-2009)</th>
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</thead>
<tbody>
<tr>
<td>Who would play something?</td>
<td>ARG0: <strong>he</strong></td>
</tr>
<tr>
<td>the soft-spoken clarinetist /</td>
<td></td>
</tr>
<tr>
<td>he</td>
<td></td>
</tr>
<tr>
<td>What would be played?</td>
<td>ARG1: <strong>tune</strong></td>
</tr>
<tr>
<td>her favorite <strong>tune</strong> from the</td>
<td></td>
</tr>
<tr>
<td>record</td>
<td>/</td>
</tr>
<tr>
<td>When would someone play</td>
<td>/</td>
</tr>
<tr>
<td>something?</td>
<td></td>
</tr>
<tr>
<td>his mother’s birthday</td>
<td></td>
</tr>
</tbody>
</table>

**match**

**precision loss**
Agreement with PropBank: Results

**Core Roles:** A0-A5

**Adjuncts:** ADV, CAU, DIR, EXT, LOC, MNR, PNC, PRD, TMP

### Agreement with PropBank: Results

**Core Roles: 86.3**

**Adjuncts: 81.4**
Agreement with PropBank: Results

**Core Roles:** A0-A5

**Adjuncts:** ADV, CAU, DIR, EXT, LOC, MNR, PNC, PRD, TMP
Agreement with PropBank: Results

**Core Roles:** A0-A5

**Adjuncts:** ADV, CAU, DIR, EXT, LOC, MNR, PNC, PRD, TMP
Inter-Annotator Agreement

- **QA Equivalence:** Same wh-word + Overlapping answers
- **Agreed QA Pairs:** Proposed by at least 2 of the 5 annotators
Inter-Annotator Agreement

- Agreed QA pairs by five annotators: 2.6-2.8 QA/verb
- One annotator can recover: 2.2-2.3 QA/verb (80%)
## Wh-words vs. PropBank Roles

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<thead>
<tr>
<th></th>
<th>Who</th>
<th>What</th>
<th>When</th>
<th>Where</th>
<th>Why</th>
<th>How</th>
<th>HowMuch</th>
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<td>414</td>
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<td>ARG1</td>
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<td>ARG2</td>
<td>85</td>
<td>364</td>
<td>2</td>
<td>49</td>
<td>17</td>
<td>51</td>
<td>74</td>
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<td>ARG3</td>
<td>11</td>
<td>62</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>16</td>
<td>31</td>
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<td>ARG4</td>
<td>2</td>
<td>30</td>
<td>5</td>
<td>11</td>
<td>2</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>ARG5</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<tr>
<td>AM-ADV</td>
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<td>44</td>
<td>9</td>
<td>2</td>
<td>25</td>
<td>27</td>
<td>6</td>
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<td>23</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>5</td>
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<tr>
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<td>89</td>
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<td>11</td>
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<td>AM-MNR</td>
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<td>8</td>
<td>4</td>
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<td>2</td>
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<tr>
<td>AM-PRD</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>AM-TMP</td>
<td>2</td>
<td>51</td>
<td>341</td>
<td>2</td>
<td>11</td>
<td>20</td>
<td>10</td>
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</tbody>
</table>
Outline

Motivation and Intuition

Data Collection and Analysis

Learning Tasks and Baselines

Future Work and Conclusion

• Semantic Role Labeling
• Our Method: QA-SRL

• Annotation Task Design
• Dataset Statistics
• Quality Analysis

• Question Generation
• Answer Identification
Question Generation

**Task**
Given sentence $s$ and target verb $v$, predict a set of questions that are *grammatical* and *answerable*.

**Motivation**
In the future, automate part of the annotation process, further reduce cost and speed up annotation.
Question Generation: Basic Idea

- Pick a role in the sentence
- Predict the right pronoun.
- Fill in the rest of the question.

\[ s = \text{They increased the rent this year.} \]
Question Generation: Basic Idea

Pick a role in the sentence
- Predict the right pronoun.
- Fill in the rest of the question.

\[ s = \text{They} \text{ increased} \text{ the rent this year}. \]

✓ Who increased something?

✗ Why was something increased?

role not present
Question Generation: Basic Idea

- Pick a role in the sentence
- Predict the right pronoun.
- Fill in the rest of the question.

$s = \text{They increased the rent this year.}$

✓ Who increased something?

✗ Why was something increased?

✗ What increased someone?
They increased the rent this year.

\[ s = \text{They increased the rent this year.} \]

\textbf{Who increased something?}  
\textbf{Wrong pronoun}

\textbf{Why was something increased?}  
\textbf{Role not present}

\textbf{What increased someone?}  
\textbf{Wrong pronoun}

\textbf{When increased someone something?}  
\textbf{Wrong template}
Question Generation: 2-Step Method

**Step 1:** Role/Pronoun Prediction as Multi-label Learning

\[ \mathcal{R} = \{\text{R0, R1, R2, R2[pp], wh, wh[pp]}\} \]
\[ \text{wh} \in \{\text{Where, When, Why, How, HowMuch}\} \]
\[ \mathcal{L} = \{\text{role:pronoun_val | role} \in \mathcal{R}\} \]

*Details can be found in paper*
Question Generation: 2-Step Method

**Step 1:** Role/Pronoun Prediction as Multi-label Learning

\[ \mathcal{R} = \{ R_0, R_1, R_2, R_2[^{pp}], wh, wh[^{pp}] \} \]

\[ wh \in \{ \text{Where, When, Why, How, HowMuch} \} \]

\[ \mathcal{L} = \{ role:pronoun\_val \mid role \in \mathcal{R} \} \]

**Step 2:** Template-based Generation with Abstract Questions

\[ R_0: \text{someone} \quad R_1: \text{something} \]

Who increased something?

*Details can be found in paper*
Question Generation: Results

<table>
<thead>
<tr>
<th>Grammatical</th>
<th>Answerable</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>67.5%</td>
<td></td>
</tr>
<tr>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>22.5%</td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td></td>
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</table>

<table>
<thead>
<tr>
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<th>prec@3</th>
<th>prec@5</th>
<th>prec@1</th>
<th>prec@3</th>
<th>prec@5</th>
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</thead>
<tbody>
<tr>
<td>newswire</td>
<td></td>
<td></td>
<td>Wikipedia</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Question Generation: Results

<table>
<thead>
<tr>
<th>Metric</th>
<th>newswire</th>
<th>Wikipedia</th>
</tr>
</thead>
<tbody>
<tr>
<td>prec@1</td>
<td>84%</td>
<td>86%</td>
</tr>
<tr>
<td>prec@3</td>
<td>78.7%</td>
<td>82%</td>
</tr>
<tr>
<td>prec@5</td>
<td>77.2%</td>
<td>86%</td>
</tr>
<tr>
<td>prec@1</td>
<td>90%</td>
<td>86%</td>
</tr>
<tr>
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<td>51.3%</td>
</tr>
<tr>
<td>prec@5</td>
<td>77.2%</td>
<td>38.4%</td>
</tr>
<tr>
<td>prec@1</td>
<td>90%</td>
<td>72%</td>
</tr>
<tr>
<td>prec@3</td>
<td>86%</td>
<td>53.3%</td>
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<tr>
<td>prec@5</td>
<td>82%</td>
<td>40%</td>
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</table>

newswire  Wikipedia
Question Generation: Results

In question prediction: 2 Question/verb answerable
In annotated data: 2.6-2.8 QA/verb
## Answer Identification

<table>
<thead>
<tr>
<th>Task</th>
<th>Given sentence $s$, target verb $v$, and question $q$, predict a word in the sentence that answers the question $q$.</th>
</tr>
</thead>
</table>

| Motivation | In the future, build an end-to-end SRL system trained by QA-SRL data. (Analogy to SRL - questions:roles, answers:arguments). |
Answer Identification: Basic Idea

\[ s = \text{The leasing office said they would increase the rent.} \]

\[ v = \text{increase} \quad q = \text{Who would increase something?} \]

Arcs from k-best dependency trees

Annotated answer spans. Space: \(2^{|s|}\)
**Answer Identification: Basic Idea**

\[ s = \text{The leasing office said they would } \textbf{increase} \text{ the rent.} \]

\[ v = \textbf{increase} \quad q = \text{Who would increase something?} \]

Arrows from k-best dependency trees

- Annotated answer spans. Space: \(2^{|s|}\)
- Training samples: \(\langle s, v, q, \text{office}\rangle, \langle s, v, q, \text{they}\rangle\) Space: \(|s|\)
Answer Identification: Basic Idea

\[ s = \text{The leasing office said they would } \boxed{\text{increase}} \text{ the rent}. \]

\[ v = \boxed{\text{increase}} \quad q = \text{Who would increase something?} \]

Arcs from k-best dependency trees

- Annotated answer spans. Space: \(2^{|s|}\)
- Training samples: \(\langle s, v, q, \text{office} \rangle, \langle s, v, q, \text{they} \rangle\) Space: \(|s|\)
- Ex. of correct predictions: “\text{office}”, “\text{leasing}”, “\text{they}”
- Ex. of wrong predictions: “\text{rent}”
Answer Identification: Results

- **Random**
  - Newswire: 26.3
  - Wikipedia: 26.9
- **Classifier**
Answer Identification: Results

- **Newswire**
  - Random: 26.3
  - Classifier: 78.7

- **Wikipedia**
  - Random: 26.9
  - Classifier: 82.3
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- Dataset Statistics
- Quality Analysis

- Question Generation
- Answer Identification

- Generalization
- Question Suggestion
- Training a Joint Parser
Future Work: Generalization

- Generalize to non-verbal predicates:
  
  **S:** The rent increase came as a *shock* to us.

  **Q:** Who was *shocked*?  **A:** us

- Generalize to other languages:

  他们 今年 涨了 房租。
  
  **Q:** 房租 什么 时候 涨了?  **A:** 今年
Future Work: Automatic Question Suggestion

Given new sentence and verb:

“I can’t believe they **increased** the rent by so much .”

![Diagram showing the process of training with annotated QA pairs leading to an automatic question generation system.]
Future Work:
Automatic Question Suggestion

Given new sentence and verb:

“I can ’t believe they *increased* the rent by so much .”

Annotated QA Pairs \(\rightarrow\) training \(\rightarrow\) Automatic Question Generator \(\rightarrow\) suggest

Who increased something ?
What increased ?
How did something increase ?
When did someone increase ?
Future Work: Automatic Question Suggestion

Given new sentence and verb:

“I can’t believe they increased the rent by so much.”

- Annotated QA Pairs
  - training
  - Automatic Question Generator
  - suggest
  - Who increased something?
  - What increased?
  - How did something increase?
  - When did someone increase?

- Human Annotators
  - write answers
Future Work: Automatic Question Suggestion

Given new sentence and verb:

“I can’t believe they **increased** the rent by so much.”

Annotated QA Pairs → training → Automatic Question Generator → suggest → write answers

Who increased something? - **they**
What increased? - **the rent**
How did something increase? - **by so much**
When did someone increase? - **unanswerable**

Human Annotators
Future Work: Training a Joint Parser

- Use question-answer pairs to train a joint parser, to improve on both syntax and semantics
- Combine with other SRL data, i.e. PropBank, FrameNet

Joint A* CCG Parsing and Semantic Role Labeling, Lewis et al., EMNLP-2015. *(Presentation: Sunday 6B)*
Contributions

• Introduced question-answer driven semantic role labeling (QA-SRL).

• High quality QA annotation with a lightweight template-based scheme.

• Two new QA-SRL learning baselines: question generation and answer identification.

• Releasing data and annotation tool - https://dada.cs.washington.edu/qasrl/
Thank You! Questions?

No Frame Inventory!

Wh-Question

Predicate

Answer

QA-SRL Project Page:
https://dada.cs.washington.edu/qasrl/