Never-Ending Learning for Open-Domain Question Answering over Knowledge Bases

Abdalghani Abujabal
Rishiraj Saha Roy, Mohamed Yahya and Gerhard Weikum
“Which film awards was Bill Carraro nominated for?”
“Which film awards was Bill Carraro nominated for?”

BillCarraro nominatedFor ?x

?x type movieAward
“Which film awards was Bill Carraro nominated for?”

BillCarraro nominatedFor ?x
?x type movieAward
Existing Approaches

- Require access to a large annotated training set
  
- Massive annotation effort, in terms of cost, time and expertise
Existing Approaches

- Require access to a large annotated training set
  - Massive annotation effort, in terms of cost, time and expertise
- Static learning methods
  - No learning after deployment
NEQA: Never Ending QA

- Initialized with a small training set
  - A handful of question-query pairs
NEQA: *Never Ending QA*

- Initialized with a small training set

- Supports continuous learning by harnessing non-expert user feedback
  - Gradually extends its template repository
  - Improves its performance over time
Outline

• Template-based QA
• NEQA
• Experiments
• Conclusion
Automated Template Generation

question

Which film award was Bill Carraro nominated for?

query

BillCarraro nominatedFor ?x ?x type movieAward
Alignment

question

Which film award was Bill Carraro nominated for?

query

BillCarraro nominatedFor ?x
?x type movieAward
Role-aligned Question-Query Pair

question

film award
NOUN(class)
Bill Carraro
NOUN(ent)
nominated
VERB(pred)
for
PREP(pred)

query

BillCarraro_{ent} nominatedFor_{pred} ?x
?x type movieAward_{class}
Role-aligned Template

question template

NOUN(class)  NOUN(ent)  VERB(pred)  PREP(pred)

query template

ent pred ?x
?x type class
Outline

• Template-based QA
• NEQA
• Experiments
• Conclusion
“Which film awards was Bill Carraro nominated for?”

BillCarraro nominatedFor ?x
?x type movieAward
"Which film awards was Bill Carraro nominated for?"

BillCarraro nominatedFor ?x
?x type movieAward

Initial Training

Template-based QA
Initial Training

Question-query bank

"Which film awards was Bill Carraro nominated for?"
BillCarraro nominatedFor ?x ?x type movieAward

Training

Template-based QA

Template bank

ent pred ?x
?x type class
Which film awards was Bill Carraro nominated for?

BillCarraro nominatedFor ?x
?x type movieAward

Template-based QA

Template bank

NOUN(class)
NOUN(ent)
VERB(pred)
PREP(pred)

ent pred ?x
?x type class

\[ u_{\text{new}} = \text{“Which president was Lincoln succeeded by?”} \]
Answering with Templates

Question-query bank

“Which film awards was Bill Carraro nominated for?”
BillCarraro nominatedFor ?x
?x type movieAward

Template-based QA

Template bank

NOUN(class) NOUN(ent) VERB(pred) PREP(pred)

Object

Subject

Modifier

ent pred ?x
?x type class

\( u_{new} = \text{“Which president was Lincoln succeeded by?”} \)
Answering with Templates

Question-query bank

“Which film awards was Bill Carraro nominated for?”
BillCarraro nominatedFor ?x
?x type movieAward

Template-based QA

Template bank

object

subject

modifier

NOUN(class)
NOUN(ent)
VERB(pred)
PREP(pred)

ent pred ?x
?x type class

$u_{new} = \text{“Which president was Lincoln succeeded by?”} $
Answering with Templates

Question-query bank

“Which film awards was Bill Carraro nominated for?”

BillCarraro nominatedFor ?x
?x type movieAward

Template-based QA

Template bank

NOUN(class)
NOUN(ent)
VERB(pred)
PREP(pred)

ent pred ?x
?x type class

$u_{new}$ = “Which president was Lincoln succeeded by?”

AbrahamLincoln succeededBy ?x
?x type president
Answering with Templates

Question-query bank

“Which film awards was Bill Carraro nominated for?”
BillCarraro nominatedFor ?x
?x type movieAward

“Which president was Lincoln succeeded by?”
AbrahamLincoln succeededBy ?x
?x type president

Template bank

Template-based QA

ent pred ?x
?x type class
Answering with Similarity Function

“Which film awards was Bill Carraro nominated for?”
BillCarraro nominatedFor ?x
?x type movieAward

“Which president was Lincoln succeeded by?”
AbrahamLincoln succeededBy ?x
?x type president

u = “What are the film award nominations that Brad Pitt received?”
Question-query bank

“Which film awards was Bill Carraro nominated for?”

BillCarraro nominatedFor ?x

?x type movieAward

………………………………………………

“Which president was Lincoln succeeded by?”

AbrahamLincoln succeededBy ?x

?x type president

Template bank

ent pred ?x

?x type class

Template-based QA

u = “What are the film award nominations that Brad Pitt received?”
"What are the film award nominations that Brad Pitt received?"
"Which film awards was Bill Carraro nominated for?"

BillCarraro nominatedFor ?x
?x type movieAward

"Which president was Lincoln succeeded by?"

AbrahamLincoln succeededBy ?x
?x type president

\[ u = \text{"What are the film award nominations that Brad Pitt received?"} \]
u = “What are the film award nominations that Brad Pitt received?”
"Which film awards was \(<E>\) nominated for?"

\(<E>\) nominatedFor \(?x\)
\(?x\) type movieAward

"Which president was \(<E>\) succeeded by?"

\(<E>\) succeededBy \(?x\)
\(?x\) type president

\(u\) = “What are the film award nominations that \(<E>\) received?”
u = “What are the film award nominations that <E> received?”
u = “What are the film award nominations that <E> received?”
u = “What are the film award nominations that <E> received?”
u = “What are the film award nominations that <E> received?”
u = “What are the film award nominations that <E> received?”
"What are the film award nominations that \( <E> \) received?"
u = “What are the film award nominations that <E> received?”
Answering with Similarity Function

Question-query bank

“Which film awards was <E> nominated for?”
<E> nominatedFor ?x
?x type movieAward

“Which president was <E> succeeded by?”
<E> succeededBy ?x
?x type president

“What are the film award nominations that <E> received?”
<E> nominatedFor ?x
?x type movieAward

Template bank

Template-based QA

Template: ent pred ?x
?x type class

Add (question, query) to question-query bank
Template Generation

**Question-query bank**

"Which film awards was <E> nominated for?"

<E> nominatedFor ?x
?x type movieAward

"Which president was <E> succeeded by?"

<E> succeededBy ?x
?x type president

"What are the film award nominations that <E> received?"

<E> nominatedFor ?x
?x type movieAward

**Template-based QA**

**Similarity-based Answering**

**Generate a template**

```
ent pred ?x
?x type class
```

```
NOUN(class) NOUN(pred) NOUN(ent) VERB(pred)
```

```
ent pred ?x
?x type class
```
Template Generation

Question-query bank

“Which film awards was <E> nominated for?”
<E> nominatedFor ?x ?x type movieAward

“Which president was <E> succeeded by?”
<E> succeededBy ?x ?x type president

“What are the film award nominations that <E> received?”
<E> nominatedFor ?x ?x type movieAward

Template-based QA

Similarity-based Answering

Template bank

ent pred ?x
?x type class

ent pred ?x
?x type class
Outline

• Template-based QA
• NEQA
• Experiments
• Conclusion
Setup

• WebQuestions dataset
  • 3775 question-answer training pairs
  • 2032 testing questions, streamed in batches of size 100
• After each batch, models are retrained
Setup (contd.)

• Initial training
  • Only 300 question/query (out of 3775)
  • 223 question-query templates

• Two feedback configurations:
  • User feedback: simulated with gold answers with $K = 5$
  • No user feedback: top-1 answer/query deemed correct
Answering Performance over Time

Cumulative Average F1

Batch Number

NEQA
NEQA-No-User-Feedback
Comparison with baselines

<table>
<thead>
<tr>
<th></th>
<th>No User Feedback</th>
<th>User Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUINT</td>
<td>25.7</td>
<td>35.9</td>
</tr>
<tr>
<td>AQQU</td>
<td>24.8</td>
<td>37.6</td>
</tr>
<tr>
<td>NEQA</td>
<td>37</td>
<td>40.8</td>
</tr>
</tbody>
</table>
Conclusion

• We presented NEQA, a KB-QA system that
  • Initialized with a small training set
  • Extends coverage of template-based methods using a similarity function
  • Introduces scope for user feedback in KB-QA
Backup Slides
Simmetry Function

Given a new utterance $u_{new}$ and a question $u_i$ from our bank:

$$score_{sim}(u_{new}, u_i) = \alpha \cdot score_{LM}(u_{new}, u_i) + (1 - \alpha) \cdot score_{w2v}(u_{new}, u_i)$$
Simularity Function

Given a new utterance $u_{new}$ and a question $u_i$ from our bank:

$$score_{sim}(u_{new}, u_i) = \alpha \cdot score_{LM}(u_{new}, u_i) + (1 - \alpha) \cdot score_{w2v}(u_{new}, u_i)$$

$$score_{LM}(u_{new}, u_i) = \prod_{w \in u_{new}} [(1 - \lambda) \cdot P_{ml}(w|u_i) + \lambda \cdot P_{ml}(w|C)]$$
Given a new utterance $u_{new}$ and a question $u_i$ from our bank:

$$score_{sim}(u_{new}, u_i) = \alpha \cdot score_{LM}(u_{new}, u_i) + (1 - \alpha) \cdot score_{w2v}(u_{new}, u_i)$$

$$score_{LM}(u_{new}, u_i) = \prod_{w \in u_{new}} [(1-\lambda) \cdot P_{ml}(w|u_i) + \lambda \cdot P_{ml}(w|C)]$$

$$score_{w2v}(u_{new}, u_i) = \frac{1}{|\mathcal{P}|} \sum_{(w_j, w_k) \in \mathcal{P}} \cos(w_{2v}(w_j), w_{2v}(w_k))$$
## Comparison with Baselines

<table>
<thead>
<tr>
<th>Method</th>
<th>Avg. Precision</th>
<th>Avg. Recall</th>
<th>Avg. F1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berant et al. (2013)</td>
<td>48.0</td>
<td>41.3</td>
<td>35.7</td>
</tr>
<tr>
<td>AQQU</td>
<td>49.8</td>
<td>60.4</td>
<td>49.4</td>
</tr>
<tr>
<td>Yih et al. (2015)</td>
<td>52.8</td>
<td>60.7</td>
<td>52.5</td>
</tr>
<tr>
<td>Savenkov et al. (2016) (w/o text)</td>
<td>49.8</td>
<td>60.4</td>
<td>49.4</td>
</tr>
<tr>
<td>Xu et al. (2016) (w/o text)</td>
<td>—</td>
<td>—</td>
<td>47.1</td>
</tr>
<tr>
<td>NEQA (No cont. learning)</td>
<td>52.1</td>
<td>60.3</td>
<td>51.0</td>
</tr>
</tbody>
</table>
Open-domain QA

• Removed training examples belong to: sports and government
• Tested on questions belong to above domains
## Open-domain QA

- Removed training examples belong to: sports and government
- Tested on questions belong to above domains

<table>
<thead>
<tr>
<th>Method</th>
<th>Avg. F1</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQQU</td>
<td>20.3</td>
</tr>
<tr>
<td>NEQA</td>
<td>50.3</td>
</tr>
</tbody>
</table>
Questions Answered via Templates Learned Online

- what is the name of the currency used in Italy?
- what is the head judge of the supreme court called?
- where did the battle of Waterloo occur?
| Question: | what films has [scarlett johansson] been in? |
| Most similar: | what movies did [zoe saldana] play in? |
| Question: | what was [sir isaac newton]'s inventions? |
| Most similar: | what inventions did [robert hooke] made? |