Question Answering over Freebase with Multi-Column Convolutional Neural Networks

Li Dong¹, Furu Wei², Ming Zhou², Ke Xu¹
¹SKLSDE, Beihang University, Beijing, China
²Microsoft Research, Beijing, China
Question Answering over Freebase

- **Freebase**
  - Large-scale knowledge base
  - A rich resource to answer open-domain questions

  **Question:**
  when did Avatar release in UK

  **Answer:**
  2009-12-17

- **Challenge**
  - Natural language questions ~ structured semantics of Freebase
  - How to bridge the gap?
Mainstream Methods (1/2)

- Semantic parsing (Berant et al., 2013; Bao et al., 2014; etc.)
  - Question \(\rightarrow\) Formal Meaning Representation \(\rightarrow\) Structured Queries
  - \(\rightarrow\) Freebase \(\rightarrow\) Answer
- Example
  - Utterance: Which college did Obama go to
  - Logical form: (and (Type University) (Education BarackObama))
  - Denotation: Occidental College, Columbia University
- Challenges
  - Huge search space
  - Lexical triggers

Example is borrowed from the website of SEMPRE
Mainstream Methods (2/2)

- Information extraction over knowledge base
  - 1. Retrieve candidate answers from Freebase
  - 2. Extract features
  - 3. Classification / Ranking

(Yao and Van Durme, 2014)

(Bordes et al., 2014a; 2014b)
Proposed Method

- Question answering -> Constraint matching
  - Answer type, answer path (relation), answer context
- Question understanding with convolutional neural networks

```
| Ranker | Answer |
|--------|--------|
|        |        |
```

```
| Matching Score |
|----------------|
|                |
```

```
| Type | Relation | Context |
|------|----------|---------|
|      |          |         |
```

```
|          |          |
|----------|----------|
|          |          |
```

```
| Multi-column Convolutional Neural Networks | Candidate Answers |
|-------------------------------------------|-------------------|
| Question                                  | Freebase™          |
```
when did Avatar release in UK

Avatar

James Cameron

film.film.directed_by

type.object.type

United States of America
m.09c7w0

film.producer

type.object.type

film.film_release_region

United Kingdom
m.07ssc

film.film_regional_release_date

2009-12-17

datetime

value_type

film.film_regional_release_date.release_date

2009-12-18

datetime

value_type
Model Overview
Embedding Candidate Answers

- Learn vector representations for candidate answers
  - (Bordes et al., 2014a; Bordes et al., 2014b)

- Answer path
  - relations between the candidate node and the entity asked in question
  - \( \text{avg}(r_1, r_2, ..., r_n) \): average of relation embeddings

- Answer context
- Answer type
Embedding Candidate Answers

- Learn vector representations for candidate answers
  - (Bordes et al., 2014a; Bordes et al., 2014b)

- Answer context
  - 1-hop entities and relations connected to the answer path
  - $\text{avg}(c_1, c_2, \ldots, c_n)$: average of context entity and relation embeddings

- Answer path

- Answer type
Embedding Candidate Answers

- Learn vector representations for candidate answers
  - (Bordes et al., 2014a; Bordes et al., 2014b)

- Answer type
  - common.topic.notable_types, value type (e.g., float, string, datetime)
  - $\text{avg}(t_1, t_2, ..., t_n)$: average of type embeddings

- Answer path

- Answer context
when did Avatar release in UK
when did Avatar release in UK

avatar release date

2009-12-17

model overview

score layer

dot product

context

answer type

answer path

answer type

shared word representations

max-pooling layer

multiple columns

convolutional layer

score layer

model overview

$S(q,a) = f_1(q)^T g_1(a) + f_2(q)^T g_2(a) + f_3(q)^T g_3(a)$

answer path

answer context

answer type

United States of America

United Kingdom

James Cameron

United States

United Kingdom

Avatar

Avatar

Dot Product

Answer

Context

Answer Type

Film

Producer

United States

United Kingdom

2009-12-18

2009-12-17

value type

film.film.release_date

film.film_regional.release_date

film.film_region.al_release_date

datetime

type.object.type

m.03_gd

m.09w09jk

m.09c7w0

m.08th54

m.0gdpl7z

m.07ssc
Model Training

- Negative instance $a'$ is randomly sampled from the set of candidate answers
- Hinge loss for $(q, a)$ and $(q, a')$
  \[ l(q, a, a') = (m - S(q, a) + S(q, a'))_+ \], where $(z)_+ = \max\{0, z\}$
- Objective function
  - $A_q$: set of correct answers
  - $R_q \subseteq C_q \setminus A_q$: set of wrong answers
  \[ \min \sum_q \frac{1}{|A_q|} \sum_{a \in A_q} \sum_{a' \in R_q} l(q, a, a') \]
- Back-propagation, AdaGrad, max-norm regularization
Inference (During Test)

1. Link to entity in Freebase
2. Retrieve candidates
3. Compute vector representations
4. Compute scores

Candidate Answers (2-hop entities/attributes)
Avatar

when did Avatar release in UK

Type | Relation | Context
Multi-column Convolutional Neural Networks
Inference (During Test)

- If there are more than one correct answers
  - Use the margin $m$ in objective function as threshold
  - Candidates whose scores are not far from the best answer are regarded as predicted results

\[
\hat{A}_q = \{ \hat{a} \mid \hat{a} \in C_q \text{ and } \max_{a' \in C_q} \{S(q, a')\} - S(q, \hat{a}) < m \} 
\]
Question Paraphrases for Multi-Task Learning

- Question understanding results of paraphrases should be same
  - who is the father of A
  - who is A’s father
- So, the vectors of paraphrases computed by neural networks should be similar
  - Hinge loss
  - Negative instance is randomly sampled

\[
l_p (q_1, q_2, q_3) = \sum_{i=1}^{3} \left( m_p - f_i (q_1)^T f_i (q_2) + f_i (q_1)^T f_i (q_3) \right)_+ \]
Experiments

- **WebQuestions (Berant et al., 2013)**
  - wh- questions collected by querying Google Suggest API
  - Annotated in Amazon Mechanical Turk
  - Train: 3023, Dev: 755, Test: 2032

- **Example**
  - Question: what is the name of justin bieber brother?
  - Url: [http://www.freebase.com/view/en/justin_bieber](http://www.freebase.com/view/en/justin_bieber)
  - Answers: {Jazmyn Bieber, Jaxon Bieber}

- **Paraphrases (Fader et al., 2013)**
  - Collected from the WikiAnswers website
  - ~2.4M questions, grouped into ~355k paraphrase clusters
Experimental Results

- Better or comparable results than baseline methods

| Method                                      | F1  | P@1 |
|---------------------------------------------|-----|-----|
| (Berant et al., 2013)                      | 31.4| -   |
| (Berant and Liang, 2014)                   | 39.9| -   |
| (Bao et al., 2014)                         | 37.5| -   |
| (Yao and Van Durme, 2014)                  | 33.0| -   |
| (Bordes et al., 2014a)                     | 39.2| 40.4|
| (Bordes et al., 2014b)                     | 29.7| 31.3|
| MCCNN (our)                                | 40.8| 45.1|
Model Analysis

- Ablation experiments
  - w/o path/type/context
    - without the specific column
  - w/o multi-column
    - tying parameters of multiple columns
  - w/o paraphrase
    - without question paraphrases
  - 1-hop
    - 1-hop paths to generate candidates

| Setting                  | F1  | P@1 |
|--------------------------|-----|-----|
| all                      | 40.8| 45.1|
| w/o path                | 32.5| 37.1|
| w/o type                 | 37.7| 40.9|
| w/o context              | 39.1| 41.0|
| w/o multi-column         | 38.4| 41.8|
| w/o paraphrase           | 40.0| 43.9|
| 1-hop                    | 29.3| 32.2|
Salient Question Words Detection

- **Saliency score**
  - How much a word affects question understanding
  - Replace a word with stop words, how much the vectors are affected

```
where is the microsoft located  ➔  Multi-Column Neural Networks  ➔  Type
```

```
<stopword> is the microsoft located  ➔  Multi-Column Neural Networks  ➔  Relation
```

```
vector distance is salience score
```

```
Type  ➔  Relation  ➔  Context
```

```
```
Salient Question Words Detection

- **Observations**
  - wh- words
  - nouns dependent of the wh- words
    - type/country/leader
  - verbs
    - speak/located
Future Work

- Question answering over unstructured text.
THANKS!
| Column 1 (Answer Path) | Column 2 (Answer Type) | Column 3 (Answer Context) |
|------------------------|------------------------|---------------------------|
| what to do in hollywood can this weekend | where be george washington originally from | where do charlie draw go to college |
| what to do in midland tx this weekend | where be george washington carver from | where do kevin love go to college |
| what to do in cancun with family | where be george bush from | where do pauley perrette go to college |
| what to do at fairfield can | where be the thame river source | where do kevin jame go to college |
| what to see in downtown asheville nc | where be the main headquarters of google | where do charlie draw go to high school |
| what to see in toronto top 10 | in what town do ned kelly and be family grow up | where do draw bree go to college wikianswer |

| Column 1 (Answer Path) | Column 2 (Answer Type) | Column 3 (Answer Context) |
|------------------------|------------------------|---------------------------|
| who found collegehumor | who be the leader of north korea today | who be judy garland father |
| who found the roanoke settlement | who be the leader of syrium now | who be clint eastwood date |
| who own skywest | who be the leader of cuba 2012 | who be emma stone father |
| who start mary kay | who be the leader of france 2012 | who be robin robert father |
| who be the owner of kfc | who be the current leader of cuba today | who miley cyrus engage to |
| who own wikimedia foundation | who be the minority leader of the house of representative now | who be chri cooley marry to |

| Column 1 (Answer Path) | Column 2 (Answer Type) | Column 3 (Answer Context) |
|------------------------|------------------------|---------------------------|
| what type of money do japanese use | what be the two official language of paraguay | what be the timezone in vancouver |
| what kind of money do japanese use | what be the local language of israel | what be my timezone in californium |
| what type of money do jamaica use | what be the four official language of nigerium | what be los angeles california time zone |
| what type of currency do brazil use | what be the official language of jamaica | what be my timezone in oklahoma |
| what type of money do you use in cuba | what be the dominant language of jamaica | what be my timezone in louisiana |
| what money do japanese use | what be the official language of brazil now | what be the time zone in france |