DIFFICULTY-CONTROLLABLE MULTI-HOP QUESTION GENERATION FROM KNOWLEDGE GRAPHS

WITH VISHWAJEET KUMAR, YUAN-FANG LI, GANESH RAMAKRISHNAN, GUILIN QI, LIANLI GAO.
• Introduction & motivation
• Related work
• MHQG: question generation over knowledge graphs
• Evaluation
• Conclusion & future work
INTRODUCTION & MOTIVATION

• Question answering over knowledge graphs: intense research focus
  • Simple questions, multiple-hop questions, more complex questions
  • Many models have been proposed recently
    • Neural network-based, thus data-hungry
  • However, progress hindered by limited availability of datasets
REPRESENTATIVE DATASETS

• Single-hop questions
  
  • [Berant et al, EMNLP’13; Bordes et al, Arxiv’15; Serban et al, Arxiv’16]

• Multi-hop questions
  
  • LC-QUAD [Trivedi et al, ISWC’17], COMPLEXWEBQUESTIONS [Talmor et al, NAACL’18], WEBQUESTIONS [Yi et al, ACL’16], PathQuestion [Zhou et al, ACL’18]

• More complex questions
  
  • CSQA [Saha et al, AAAI’18]
However...

• Limited in size
  • Simple questions are abundant (30M), but only simple
  • Complex questions: a few thousands
• (Semi-)manually created & curated
  • Expensive to augment & extend
MULTI-HOP QUESTIONS: TWO EXAMPLES

- What is the name of the spouse of Henry I Duke of Guise’s mom?

- What languages are spoken in Norway?
OUR CONTRIBUTIONS

• A novel Transformer-based model for generating multi-hop questions from subgraphs with
  • Answer encoding
  • Difficulty modelling, estimation & control
• Our technique is able to generate questions of high quality
• Dataset and code available: https://github.com/liyuanfang/mhqg
OUTLINE

- Introduction & motivation
- Related work
- MHQG: question generation over knowledge graphs
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THREE MOST RELEVANT AREAS

• Question answering over knowledge graphs (or QALD)
  • Simple vs multi-hop vs complex
  • Semantic parsing based, Web search-based, neural symbolic-based...

• Question generation over KG

• Most are template-based
  • Serban et al [Arxiv’16]: neural network-based, single-triples only

• Question generation over text
  • Many recent works, including ours
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PROBLEM FORMULATION

• Modelled as a graph-to-sequence learning problem

• Given a subgraph of facts (triples) \( G = \{f_1, \ldots, f_n\} \)

• And (optionally) answer entities \( E_A \)

• Learn to generate

\[
Q^* = \arg\max_Q P(Q \mid G, E_A; \Theta)
\]

\[
= \arg\max_{w_1, \ldots, w_m} \prod_{i=1}^{m} P(w_i \mid w_1, \ldots, w_{i-1}, G, E_A; \Theta)
\]
THE TRANSFORMER-BASED ARCHITECTURE.
Knowledge Graph Encoding

- Triple embedding: concat $h$, $r$, $t$
- Answer embedding: $\text{Linear}(\text{ReLU}(Wx + b))$
- Given graph: $G \in \mathbb{R}^{n \times d_g}$
- Encodes it as: $Z = (z_1, \cdots, z_n) \in \mathbb{R}^{n \times d_v}$
- Making use of multi-head attention
  - transform $G$ into $Q$, $K$, $V$
DIFFICULTY MODELLING & ESTIMATION

- **Confidence** of entity linking in the question
  - Higher $\rightarrow$ easier

- **Selectivity** of surface form of entities in the graph
  - Less selective $\rightarrow$ more confusing $\rightarrow$ harder

- E.g., “John Smith” vs “Elon Musk”
**QUESTION DECODER**

- User-tunable difficulty level
- 2-dimensional array $\mathbf{x} \in \{0, 1\}^2$
  - $(0, 1)$: easy, $(1, 0)$: hard

$$\text{DE}(\mathbf{x}) \in \mathbb{R}^{d_g}$$

$$= \text{Linear}(\text{ReLU}(\mathbf{Wx} + \mathbf{b}))$$
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**DATASETS**

- **WEBQUESTIONS** [Yi et al, ACL’16] & **COMPLEXWEBQUESTIONS** [Talmor et al, NAACL’18]
- With Freebase IDs
- **PathQuestion** [Zhou et al, ACL’18]
- Verbalised entities only

<table>
<thead>
<tr>
<th>DATASET</th>
<th>#E</th>
<th>#P</th>
<th>#HOPS</th>
<th>#INSTANCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQ</td>
<td>25,703</td>
<td>672</td>
<td>2 TO 100</td>
<td>22,989</td>
</tr>
<tr>
<td>PQ</td>
<td>7,250</td>
<td>378</td>
<td>2, 3</td>
<td>9,731</td>
</tr>
</tbody>
</table>
BASELINES

State-of-the-art QG model (for text)

• Learning to ask (L2A) [Du et al, ACL’17]

• Linearise graphs as sequences

EVALUATION METRICS

• Automatic evaluation

• BLEU, ROUGE-L, METEOR

• Manual evaluation

• Syntax, semantics, difficulty
## Automatic Evaluation

<table>
<thead>
<tr>
<th>Model</th>
<th>WQ</th>
<th>PQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BLEU</td>
<td>ROUGE-L</td>
</tr>
<tr>
<td>L2A</td>
<td>6.01</td>
<td>26.95</td>
</tr>
<tr>
<td>MHQG</td>
<td>11.49</td>
<td>34.61</td>
</tr>
<tr>
<td>MHQG+AE</td>
<td>11.57</td>
<td>35.53</td>
</tr>
</tbody>
</table>

AE: answer encoding
**MANUAL EVALUATION**

<table>
<thead>
<tr>
<th>MODEL</th>
<th>WQ</th>
<th>PQ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SYNTAX</td>
<td>SEMANTICS</td>
</tr>
<tr>
<td>L2A</td>
<td>78 (97)</td>
<td>80 (95)</td>
</tr>
<tr>
<td>MHQG</td>
<td>79 (75)</td>
<td>83 (81)</td>
</tr>
<tr>
<td>MHQG+AE</td>
<td>98 (73)</td>
<td>97 (76)</td>
</tr>
</tbody>
</table>

AE: answer encoding
### SOME DIFFICULTY-TUNABLE EXAMPLES

<table>
<thead>
<tr>
<th>GRAPH</th>
<th>EASY</th>
<th>HARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>m.0gtqy5p location m.0r0m6 &lt;t&gt;</td>
<td>where did bob dylan live?</td>
<td>where did the subject of the film &quot;I’m Not There&quot; live?</td>
</tr>
<tr>
<td>m.0gtqxxq location m.0fpzwf &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.01vrncs places_lived m.03pnpl8 &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.01vrncs film.film_subject.films m.0djlx &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.03pnpl8 location m.0h1k6 &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.0gtqxxk location m.02_286 &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.01vrncs places_lived m.0gtqy5p &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.01vrncs places_lived m.0gtqxxk &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.0gtqy5h location m.0wjjx &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.01vrncs places_lived m.0gtqxxq &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.01vrncs places_lived m.0gtqy5h &lt;t&gt;</td>
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<td></td>
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<tr>
<td>MODEL COMPARISON (1)</td>
<td></td>
<td></td>
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<tr>
<td>-----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GRAPH</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.0j9l89y office_position_or_title m.0j6tpbb &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.0hqg6pb office_position_or_title m.0j6tpbb &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.03gj2 official_language m.02ztjwg &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.03gj2 governing_officials m.0hqg6m3 &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.03gj2 governing_officials m.0j9l89y &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.03gj2 governing_officials m.0hqg6pb &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.0hqg6m3 office_position_or_title m.0j6tpbb &lt;t&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>L2A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>what language is spoken in the governmental jurisdiction?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MHQG</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>what is the spoken language in the country with governmental position prime minister of hungary?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MHQG + AE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>what language is spoken in the governmental jurisdiction where prime minister of hungary holds office?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Model Comparison (2)

| GRAPH                                      | m.0d04z6 currency_used m.049p2z <t>  
|                                            | m.0d04z6 national_anthem m.048z_y1 <t>  
|                                            | m.0d04z6 currency_used m.049p6c <t>  
|                                            | m.048z_y1 anthem m.01lg5j <t>  |
| L2A                                        | the country that contains uses what type of currency? |
| MHQG                                       | what is the currency used in the country with la bayamesa as its national anthem? |
| MHQG + AE                                  | what currency is used in the country with national anthem la bayamesa? |
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• MHQG: a novel Transformer-based model for generating **multi-hop questions** from subgraphs

  • Difficulty modelling, estimation & control

• **Future work**

  • Generating even more complex questions

  • More refined difficulty estimation

  • QA & QG as dual tasks
THANK YOU!

ANY QUESTIONS?
REFERENCES


• Kumar, V., Boorla, K., Meena, Y., Ramakrishnan, G., Li, Y.F.: Automating reading comprehension by generating question and answer pairs. In: PAKDD 2018

• Saha, A., Pahuja, V., Khapra, M.M., Sankaranarayanan, K., Chandar, S.: Complex sequential question answering: Towards learning to converse over linked question answer pairs with a knowledge graph. In: AAAI 2018
**REFERENCES**


