

Complex Factoid Question Answering with a Free-Text Knowledge Graph

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Outline

- Introduction
- Motivation
- Graph Construction
- Graph Modeling
- Experiments
- Summary

Factoid Question Answering

- Questions ask precise facts about **entities**
- Example:
Q: Who was the last person to live in the Forbidden City?
A: Puyi

Factoid Question Answering



Waston on Final Jeopardy! Question

Question

(**U.S. CITIES**) Its largest airport is named for a World War II hero; its second largest, for a World War II battle.

Waston: Toronto Answer: Chicago

Why Toronto not Chicago? From IBM principle investigator David Ferrucci:

- Question Category
- Entity Ambiguity (A small city in Illinois called Toronto)
- Unable to locate sub-part of the question

Knowledge Graph Question Answering (KGQA)

- Search the answer from a KG

 Freebase™


WIKIDATA


DBpedia


yago
select knowledge

Knowledge Graph Question Answering (KGQA)

- Search the answer from a KG
- Can answer **complex** questions, Example:
 - Q: who was the [last] [emperor of] China?
 - A: (? :person, *Emperor of*, China, max:time) → Puyi

 Freebase™



 DBpedia

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select knowledge

Knowledge Graph Question Answering (KGQA)

- Search the answer from a KG
- Can answer **complex** questions, Example:
 - Q: who was the [last] [emperor of] China?
 - A: (?:person, *Emperor of*, China, max:time) → Puyi
- Knowledge Graph is brittle and incomplete
 - Google Vault 570M entities, 14 times than Freebase
 - 35K relations, similar to Freebase

 Freebase™



 DBpedia

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select knowledge

Question Answering on Free-Text (Machine Reading)

- Answer questions directly from text corpora
 - Extract a span from paragraph(s) as the answer



Natural Questions

A Benchmark for Question Answering Research.

Question Answering on Free-Text (Machine Reading)

- Answer questions directly from text corpora
 - Extract a span from paragraph(s) as the answer
- Strong accuracy on benchmark machine reading datasets



Natural Questions

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Complex Question Answering

- Current Machine Reading approaches only focus on single evidence
 - Question is complex: synthesizing multiple evidence

Complex Question Answering

- Current Machine Reading approaches only focus on single evidence
 - Question is complex: synthesizing multiple evidence
- Uncommon relations in the question

Complex Question Answering

Quizbowl Question (QbLink Dataset)

Vermeer painted a series of cityscapes of this Dutch city, including The Little Street. This city highly influenced the Dutch Golden Age in various aspects.

Answer: Delft

Complex Question Answering

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Motivation: Combine Best of the World

Freebase™



Motivation: Combine Best of the World

- Wikipedia Graph Construction
- Question Grounding
- Graph Modeling

Wikipedia Graph Construction

- Build knowledge graph from Wikipedia
 - Nodes are Wikipedia entities



Wikipedia Graph Construction

- Build knowledge graph from Wikipedia
 - Nodes are Wikipedia entities
 - Free text edges connect nodes



Wikipedia Graph Construction

- Build knowledge graph from Wikipedia
 - Nodes are Wikipedia entities
 - Free text edges connect nodes
 - Sentences that pairs of entities **co-occur**



Question Grounding - Question Entity Nodes

- Identify entities in the question by entity linking tools

Question: **Vermeer** painted a series of cityscapes of this Dutch city, including **The Little Street**. This city highly influenced the **Dutch Golden Age** in various aspects.

Answer: *Delft*



Vermeer



The
Little
Street



Dutch
Golden
Age

Question Grounding - Candidate Entity Nodes

- Candidate Entity Nodes directly connect to the entities related to the question

Question: **Vermeer** painted a series of cityscapes of this Dutch city, including **The Little Street**. This city highly influenced the **Dutch Golden Age** in various aspects.

Answer: *Delft*



Vermeer



The
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Question Grounding - Node Gloss

- Use the gloss as the node features

Question: **Vermeer** painted a series of cityscapes of this Dutch city, including **The Little Street**. This city highly influenced the **Dutch Golden Age** in various aspects.

Answer: *Delft*

Vermeer was a Dutch Baroque Period painter who specialized in ...



Vermeer

The Little Street is a painting by the Dutch painter ...



The Little Street

The **Dutch Golden Age** was a period in the history of the Netherlands ...



Dutch Golden Age

Delft



Delft is a city in the province of South Holland, Netherlands ...

Amsterdam



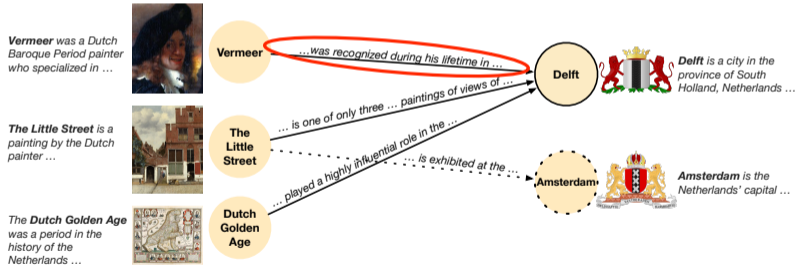
Amsterdam is the Netherlands' capital ...

Question Grounding - Evidence Edges

- Evidence signals to find the correct answer

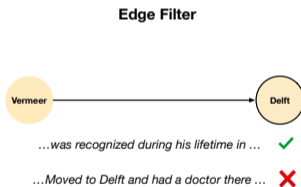
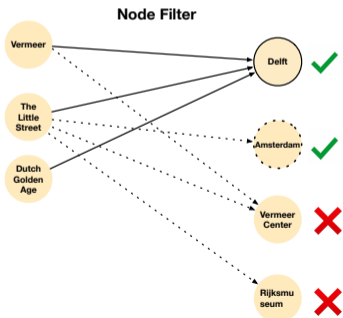
Question: **Vermeer** painted a series of cityscapes of this Dutch city, including **The Little Street**. This city highly influenced the **Dutch Golden Age** in various aspects.

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Graph Pruning

- Node Filter
 - Fine-tuning BERT ranker
- Edge Filter
 - TFIDF similarity to question

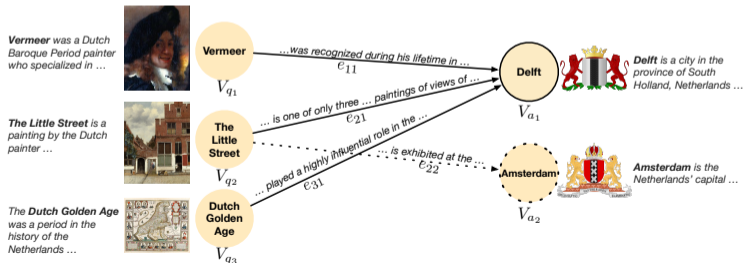


Free-Text Graph Modeling

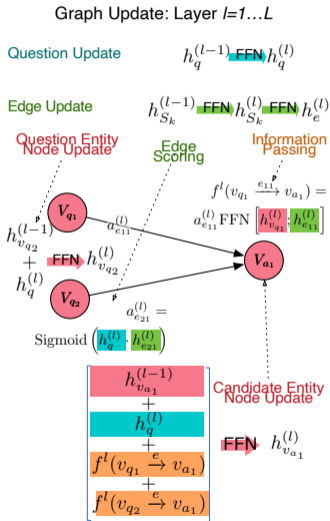
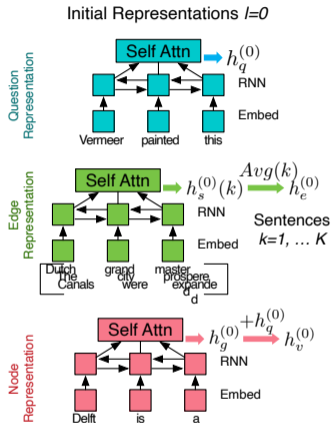
- Goal: find the correct answer node from the Candidate Entity Nodes
- Motivations for model design:
 - Graph Connectivity
 - Edge Relevance
 - Node Relevance

Question: **Vermeer** painted a series of cityscapes of this Dutch city, including **The Little Street**. This city highly influenced the **Dutch Golden Age** in various aspects.

Answer: *Delft*

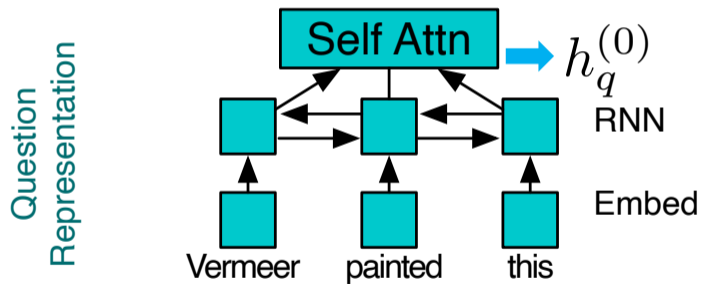


Graph Modeling



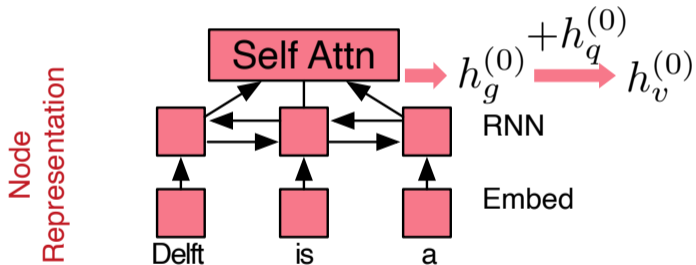
Graph Modeling - Initial Question Representation

Initial Representations $l=0$



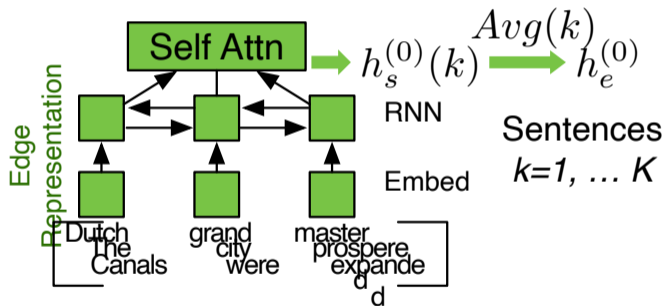
Graph Modeling - Initial Node Representation

Initial Representations $l=0$



Graph Modeling - Initial Edge Representation

Initial Representations $l=0$

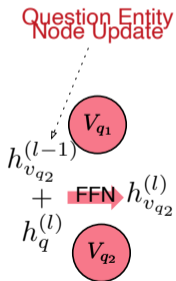


Graph Modeling - Representation Forwarding

Graph Update: Layer $l=1 \dots L$

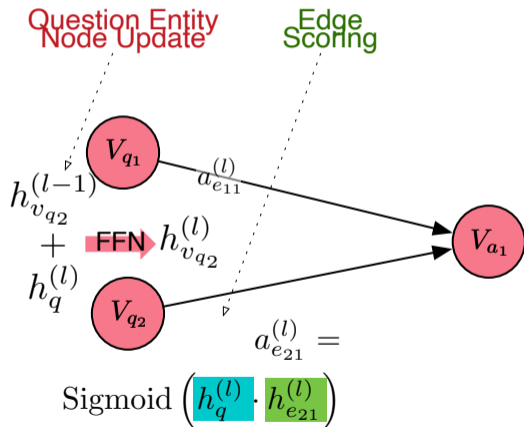
Question Update $h_q^{(l-1)} \xrightarrow{\text{FFN}} h_q^{(l)}$

Edge Update $h_{S_k}^{(l-1)} \xrightarrow{\text{FFN}} h_{S_k}^{(l)} \xrightarrow{\text{FFN}} h_e^{(l)}$



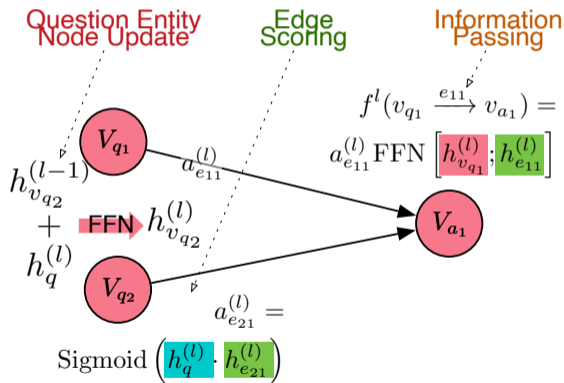
Graph Modeling - Edge Scoring

Graph Update: Layer $l=1 \dots L$



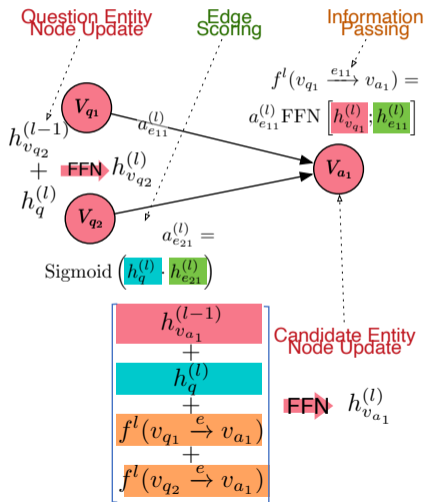
Graph Modeling - Information Passing

Graph Update: Layer $l=1 \dots L$



Graph Modeling - Candidate Nodes Update

Graph Update: Layer $l=1 \dots L$



DELFT: Decipher Entity links from Free Text

- Free-text KG construction
- Question Grounding
- Graph Modeling

Experiments Datasets: QbLink

Example

Q: Name this person ridiculed for the film Bedtime for Bonzo by incumbent Pat Brown during an election which he won to become governor of California.

A: Ronald Reagon

Experiments Datasets: QANTA

Example

Q: Following one of these events, the Casa Pia children's education center was established. Trajan and Hadrian experienced one of these events in Antioch and suffered minor injuries. After one of these events, a city rallied around the phrase, "Bury the dead and heal the living." The aftermath of one of these events in 1923 saw the massacre of ethnic Koreans. That one of these events on the Kanto plain of Japan was exacerbated by the ensuing tsunami, a common consequence of these events. For 10 points, name this type of natural disaster that has often affected San Francisco due to the activity of the San Andreas fault.

A: Earthquakes

Experiments Datasets: TriviaQA

- Answerable by Wikipedia entities

Example

Q: What was the occupation of Lovely Rita according to the song by the Beatles?

A: Traffic Warden

	qbLink	QANTA	TriviaQA
Training	42219	31489	41448
Dev	3276	2211	4620
Test	5984	4089	5970
# Tokens	31.7 ± 9.4	129.2 ± 32.0	16.5 ± 8.6
# Entities	6.8 ± 2.4	21.2 ± 7.3	2.2 ± 1.3
% 1-3 Entities	9.6%	0	86.9%
% 4-6 Entities	36.7%	0	13.1%
% 7-9 Entities	36.5%	0	0
% 10+ Entities	17.1%	100%	0

Graph Coverage

	qbLink	QANTA	TriviaQA
Answer Recall after Filtering	87.6%	83.9%	86.4%
Answer Recall within Two Hops along DBpedia Graph*	38%	-	-
# Edges to Correct Answer Node (+)	5.07 ± 2.17	12.33 ± 5.59	1.87 ± 1.12
# Edges to Candidate Entity Node (-)	2.35 ± 0.99	4.41 ± 2.02	1.21 ± 0.35
# Evidence Sentences per Edge (+)	12.3 ± 11.1	8.83 ± 6.17	15.53 ± 17.52
# Evidence Sentences per Edge (-)	4.67 ± 3.14	4.48 ± 1.88	3.96 ± 3.33

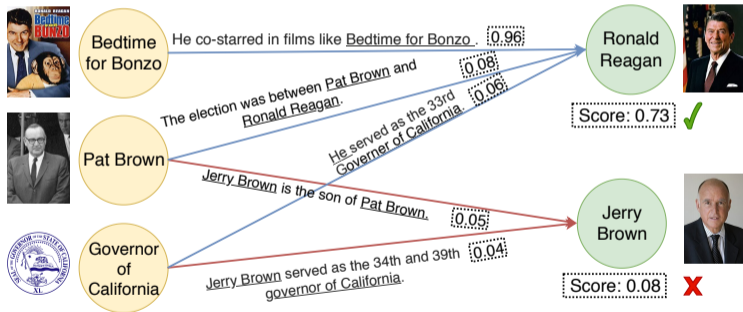
- DELFT's graph is dense
- The graph separates the correct answer by its structure

Baselines

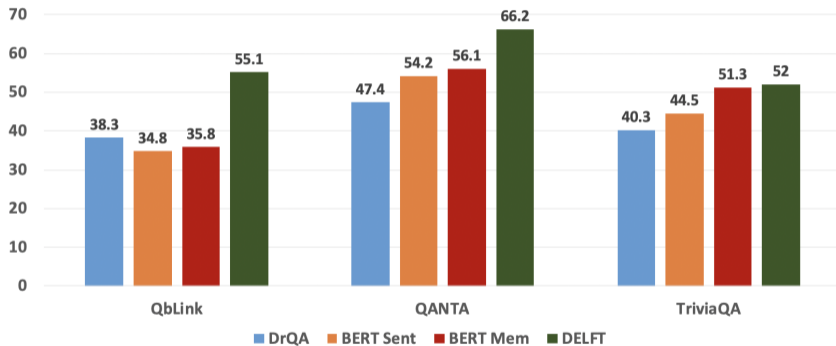
- Machine Reading (DrQA)
- BERT Ranker
- BERT Memory Network

Graph Visualization

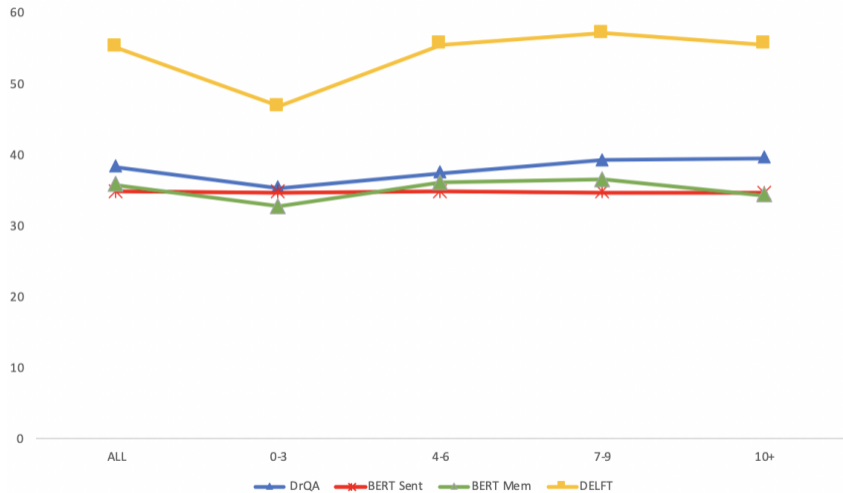
Q: Name **this person** ridiculed for the film Bedtime for Bonzo by incumbent Pat Brown during an election which he won to become governor of California.



Overall Results



QbLink Results by Question Entities



Error Analysis

Question

Name this European nation which was divided into Eastern and Western regions after *World War II*.

DELFT: Yumen Pass Answer: Germany

Reason: Can't extract the key evidence sentence.

Error Analysis

Question

Telemachus is the son of this hero, who makes a really long journey back home after the *Trojan War* in an epic poem by *Homer*.

DELFT: Penelope Answer: Odysseus

Reason: Answer and predicted entities share most of the extracted evidence.

Summary

- Inherit KGQA style reasoning with the widely available free-text evidence
- Build high coverage and dense free-text knowledge graph
- A novel GNN to find the answer by aggregating multiple evidences
- Future work: dialogue, language modeling, ad hoc search
- Code, Wikipedia Knowledge graph and question grounded graph is at delft.qanta.org