Explainable Conversational Question Answering over Heterogeneous Sources

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Conversational Question Answering

Who wrote the book Angels and Demons?  
Dan Brown

The main character in his books?  
Robert Langdon

Who plays him in the films?  
Tom Hanks

To which headquarters was Robert flown in the book?  
CERN

How long is the novel?  
768 pages

⇒ Single information source (KB / text corpora / infoboxes / tables) not sufficient
⇒ By combining heterogeneous sources the answer coverage is enhanced
⇒ Information redundancy can help improve accuracy
Desiderata and Contributions

Leverage **heterogeneous** information sources for conversational QA

**No restriction to specific information source**

Make process **explainable**
- **Intermediate** representations in **symbolic** space

Avoid expensive annotations
- **Distant supervision** from **raw** sequences of **QA pairs**
Overview

Question Understanding

Derive self-sufficient representation of user intent

Evidence Retrieval

Obtain evidences from heterogeneous sources

Heterogeneous Answering

Derive the answer from the set of evidences

Context entity: Angels and Demons

Question entity: Robert Langdon

Relation: who plays him in the films

Answer type: human

Structured Representation

Angels & Demons, cast member, Tom Hanks, (character, Robert Langdon)

Relevant Evidences

Tom Hanks

Answer

Who wrote the book Angels and Demons?

Dan Brown

the main character in his books?

Robert Langdon

who plays him in the films?

EXPLAIGNN

Christmann et al. SIGIR 2023

CONVINSE

Christmann et al. SIGIR 2022

Who wrote the book Angels and Demons?

Dan Brown

the main character in his books?

Robert Langdon

who plays him in the films?

Tom Hanks

Answer

EXPLAIGNN

Christmann et al. SIGIR 2023

CONVINSE

Christmann et al. SIGIR 2022
Structured Representation (SR)

⇒ Capture information need in a **structured** way
⇒ Relaxed **categorization** into
  ⇒ Context entity, question entity, relation, expected answer type

**Context entity:** *Angels and Demons*
**Question entity:** *Dan Brown*
**Relation:** *the main character in his books*
**Answer type:** *fictional character*
Who wrote the book Angels and Demons?

Dan Brown

Who is the main character in his books?

Robert Langdon

Who plays him in the films?

Structured Representation (SR)

Context entity: Angels and Demons
Question entity: Robert Langdon
Relation: who plays him in the films
Answer type: human

Fine-tuned BART model
(via distant supervision)
Evidence Retrieval

CLOCQ
[Christmann et al. WSDM 2022]

Structured Representation (SR)

Context entity: Angels and Demons
Question entity: Robert Langdon
Relation: who plays him in the films
Answer type: human

Question entities

Entity-centric Wikipedia retrieval

KB-facts

Text-snippets
Table-records
Infobox-entries

Angels & Demons (film series)
Angels & Demons (novel series)
Angels & Demons (soundtrack)
Robert Langdon (film series)
Robert Langdon (character)

Angels & Demons, cast member, Tom Hanks, (character, Robert Langdon)

Game of Thrones, Darsteller, Peter Dinklage, (Rolle, Tyrion Lannister)

Game of Thrones, Darsteller, Peter Dinklage, (Rolle, Tyrion Lannister)

Game of Thrones, Darsteller, Peter Dinklage, (Rolle, Tyrion Lannister)

Game of Thrones, Darsteller, Peter Dinklage, (Rolle, Tyrion Lannister)
Professor Robert Langdon is a fictional character created by author Dan Brown for his Robert Langdon book series.

who plays him in the films?

Robert Langdon, Portrayed by, Tom Hanks (film series), Ashley Zukerman (The Lost Symbol)

Plain textual forms... ➞ Incorporate structure using shared entities!
Robert Langdon is a fictional character created by author Dan Brown for his Robert Langdon book series.
Evidences

**KB**
- Angels & Demons, cast member, Tom Hanks, character, Robert Langdon
  - "Angels & Demons" → Angels & Demons (film),
  - "Tom Hanks" → Tom Hanks (human),
  - "Robert Langdon" → Robert Langdon (fictional character)

**TEXT**
- Professor Robert Langdon is a fictional character created by author Dan Brown for his Robert Langdon book series.
  - "Robert Langdon" → Robert Langdon (fictional character),
  - "Dan Brown" → Dan Brown (human),

**INFO**
- Robert Langdon, Portrayed by, Tom Hanks (film series), Ashley Zukerman (The Lost Symbol)
  - "Robert Langdon" → Robert Langdon (fictional character),
  - "Tom Hanks" → Tom Hanks (human),
  - "Ashley Zukerman" → Ashley Zukerman (human),
  - "The Lost Symbol" → The Lost Symbol (tv series)

Leverage href anchors!

Obtain entity mappings for evidences!

who plays him in the films?
Robert Langdon, Portrayed by Tom Hanks (film series), Ashley Zukerman (The Lost Symbol)

who plays him in the films?
Heterogeneous graphs often have hundreds of nodes. Showing such large graphs to end users is impractical. Idea: Train GNN to predict node relevance. Iteratively apply to reduce size of graph.

who plays him in the films?
Robert Langdon, performer, Tom Hanks

Robert Langdon, fictional character, Tom Hanks

Robert Langdon, character, Tom Hanks

Professor Robert Langdon is a fictional character created by author Dan Brown for his Robert Langdon book series.

Robert Langdon, novel series

Dan Brown, human

who plays him in the films?
GNN Encoder

**Evidence** $\epsilon$: 
Robert Langdon, performer, Tom Hanks  
$\xrightarrow{}$  
LM (SR $\circ$ $\epsilon$)  
$\xrightarrow{}$  
Robert Langdon, performer, Tom Hanks  
(evidence encoding)

**Entity** $e$: 
Robert Langdon  
$\xrightarrow{}$  
LM ($\text{SR} \circ e \circ \text{type}(e)$)  
$\xrightarrow{}$  
Robert Langdon  
(entity encoding)

**SR:** 
[Angels and Demons | Robert Langdon | who plays him in the films | human]  
$\xrightarrow{}$  
LM (SR)  
$\xrightarrow{}$  
[Angels and Demons | Robert Langdon | who plays him in the films | human]  
(SR encoding)

**LM:** Pre-trained language model (DistilRoBERTa) encodings + mean pooling  
⇒ Leverage **cross-attention with SR** in encoder  
⇒ Obtain **question-relevant encodings**
 ⇒ **Message passing** in local neighborhoods
 ⇒ Weight messages by **SR attention**
 ⇒ Distribute **only question-relevant** information

**Robert Langdon**, performer, **Tom Hanks**

**The Lost Symbol**, Ashley Zukerman as Robert Langdon, a Harvard professor of Symbology.
Robert Langdon, performer, Tom Hanks
Robert Langdon, performer, Ashley Zukerman
The Lost Symbol, Ashley Zukerman as Robert Langdon, a Harvard professor of Symbology

Attention (\(\varepsilon, SR\))

- Message passing in local neighborhoods
- Weight messages by **SR attention**
- Distribute only question-relevant information

**Context entity:** Angels and Demons
**Question entity:** Robert Langdon
**Relation:** who plays him in the films
**Answer type:** human

- Professor Robert Langdon is a fictional character created by author Dan Brown for his Robert Langdon book series.
- Robert Langdon, portrayed by Tom Hanks, is a Harvard professor of Symbology.
Message Passing

ReLU \[ \text{linear} \left( \begin{array}{c}
+ \\
+ \\
+ \\
+ \\
+ \\
+ \\
\end{array} \right) + \begin{array}{c}
0.21 \\
0.18 \\
0.24 \\
0.03 \\
0.09 \\
0.12 \\
0.02 \\
0.11 \\
\end{array} \] + \begin{array}{c}
\text{Robert Langdon} \\
\text{fictional character} \\
\end{array} \]

\[ \Rightarrow \text{Linear transformation layer (neural)} \]
\[ \Rightarrow \text{Project messages from neighbors} \]
\[ \Rightarrow \text{ReLU activation function} \]
\[ \Rightarrow \text{Process equivalent for evidences} \]
Score Prediction

\[ \text{score}(\text{Robert Langdon}) = \text{softmax} \left( \begin{array}{c} \text{Robert Langdon} \end{array} \right) \cdot \text{linear} \left( \begin{array}{c} \text{ Robert Langdon } \end{array} \right) \]

\[ \text{score}(\text{Robert Langdon, performer, Tom Hanks}) = \text{softmax} \left( \begin{array}{c} \text{ Robert Langdon, performer, Tom Hanks } \end{array} \right) \cdot \text{linear} \left( \begin{array}{c} \text{ Robert Langdon, performer, Tom Hanks } \end{array} \right) \]

⇒ After L layers, **compute** entity and evidence scores
⇒ **Binary-cross-entropy** loss for both (classification) tasks
⇒ **Entity labels:** gold answers are labeled with 1, other entities with 0
⇒ **Evidence labels:** evidences directly connected to gold answers labeled with 1
⇒ **Multi-task learning:** loss is weighted combination
GNN Scoring

⇒ Obtain scores for every evidence and entity
⇒ Use scores to identify subgraph for next iteration
⇒ Iteratively apply this scheme

who plays him in the films?
Training and Iterative Inference

- **Train** GNNs on **full graphs**
- **Apply iteratively** at **inference** time
- Helps to **improve** performance (+ more robust)

- Initialize
- **Pruning iterations**
- **Answer prediction**

- **Predicted answer**
Main Results – P@1

**ConvMix dataset:**
ConvQA over heterogeneous sources

EXPLAIGNN outperforms best baseline significantly

<table>
<thead>
<tr>
<th>Model</th>
<th>Precision at 1 (P@1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question Resolution + BM25 + FiD</td>
<td>0.282</td>
</tr>
<tr>
<td>Question Rewriting + BM25 + FiD</td>
<td>0.271</td>
</tr>
<tr>
<td>CONVINSE</td>
<td>0.342</td>
</tr>
<tr>
<td>CONVINSE (top-k FiD)</td>
<td>0.343</td>
</tr>
<tr>
<td>EXPLAIGNN</td>
<td>0.406*</td>
</tr>
</tbody>
</table>
Main Results – MRR

**ConvMix dataset:**
ConvQA over heterogeneous sources

Mean reciprocal rank (MRR)

<table>
<thead>
<tr>
<th>Approach</th>
<th>MRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question Resolution + BM25 + FiD</td>
<td>0.289</td>
</tr>
<tr>
<td>Question Rewriting + BM25 + FiD</td>
<td>0.278</td>
</tr>
<tr>
<td>CONVINSE</td>
<td>0.365</td>
</tr>
<tr>
<td>CONVINSE (top-k FiD)</td>
<td>0.378</td>
</tr>
<tr>
<td>EXPLAIGNN</td>
<td>0.471*</td>
</tr>
</tbody>
</table>

*Margin to baselines increases further for MRR metric*
Results – Per Information Source(s)

ConvMix dataset:
ConvQA over heterogeneous sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Precision at 1 (P@1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KB</td>
<td>0.363</td>
</tr>
<tr>
<td>Text</td>
<td>0.233</td>
</tr>
<tr>
<td>Table</td>
<td>0.064</td>
</tr>
<tr>
<td>Info</td>
<td>0.256</td>
</tr>
<tr>
<td>ALL</td>
<td>0.406</td>
</tr>
</tbody>
</table>

Best performance when integrating all sources
Test Robustness

ConvQuestions dataset
ConvQA over KBs

Out-of-the-box EXPLAIGNN obtains state-of-the-art performance on competitive ConvQuestions dataset

Mean reciprocal rank (MRR)

- CONVEX
- Focal Entity
- OAT
- OAT (gold seed entity)
- CONQUER
- PRALINE
- KRR (gold seed entity)
- EXPLAIGNN (KB-only)
- EXPLAIGNN
Claim: EXPLAIGNN can provide explanations that end users can understand
“EXPLAIGNN-ation”

Who wrote the book Angels and Demons?
- Dan Brown

the main character in his books?
- Robert Langdon

who plays him in the films?
- Tom Hanks

System interpretation
- **Context entity**: Angels and Demons
- **Current entity**: Robert Langdon
- **Relation**: who plays him in the films
- **Expected answer type**: human

Supporting evidences
1. Angels & Demons, cast member, Tom Hanks, character, Robert Langdon
2. Angels & Demons, Starring, Tom Hanks.
4. Robert Langdon, Created by, Dan Brown.
5. Professor Robert Langdon is a fictional character created by author Dan Brown for his Robert Langdon book series.
Claim: EXPLAIGNN can provide explanations that end users can understand
⇒ Needs to be shown with end users

Idea:
⇒ Randomly sample answered instances for which answer is correct or incorrect
⇒ Present user with conversational history, answer prediction, and explanation (SR + evidences)
⇒ Let user decide whether predicted answer is correct
⇒ Ask user about their certainty and the reasons for their certainty/uncertainty
⇒ Prune cases in which user is certain/uncertain for the wrong reasons
   e.g. because of prior knowledge or commonsense
“EXPLAIGNN-ability” User Study

Collected 1,200 judgements via Amazon Mechanical Turk (AMT)
(Masters only, >95% acceptance rate, honeypot questions)
⇒ 771 left after pruning irrelevant cases (answer known,...)

Results

P (User certain) = 0.798
P (User correct) = 0.761
P (User correct | User certain) = 0.792

⇒ Indicates that explanations are indeed comprehensible by end users
Conclusion

★ We propose EXPLAIGNN
  ★ An explainable pipeline for ConvQA
  ★ Operates over heterogeneous sources (KB / text corpora / infoboxes / tables)
  ★ Intent-explicit structured representation of questions
  ★ Large answering graph is iteratively reduced in size to obtain answer and supporting evidences

★ EXPLAIGNN significantly improves over baselines on ConvMix
★ Crowdsourced user study demonstrates explainability

★ Further information: explaignn.mpi-inf.mpg.de

Thank you!