

Question Answering Systems

Template-based QA over Knowledge Graphs

Rishiraj Saha Roy

Max Planck Institute for Informatics, Germany

Lecture starts
at 14:15

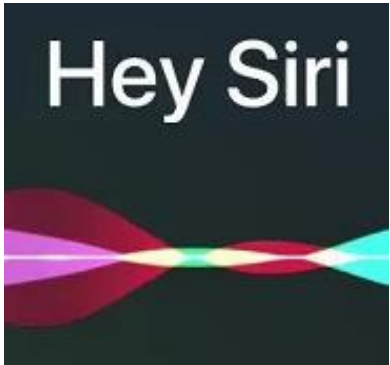
Mute your mic
Turn off videos



Advanced Lecture (6 ECTS) Question Answering Systems

Rishiraj Saha Roy, MPI for Informatics
Tuesdays 14:00 – 16:00 HS001 + Zoom

<https://www.mpi-inf.mpg.de/question-answering-systems/>



who is the lead actor in avengers infinity war

which awards has messi won

what is the dwarf language called in lord of the rings

Avengers: Infinity War

FSK 12 2018 · Sci-fi/Action · 2h 40m

THE MOVIE REVIEWS CAST PEOPLE ALSO ASK FOR

Robert Downey, Jr.
Iron Man

Tom Holland
Spider-Man

Chris Hemsworth
Thor

Lionel Messi

Footballer

OVERVIEW AWARDS PEOPLE ALSO ASK FOR

FIFA World Player of the Year 2009

European Golden Shoe 2018, 2017, 2013, ...

Pichichi Trophy 2019, 2018, 2017, ...

Ballon d'Or 2019, 2009

Khuzdul

Khuzdul was the **language** of the **Dwarves**, written in the 50-letter Cirth script (Runes). It appears to be structured, like real-world Semitic **languages**, around the triconsonantal roots: kh-z-d, b-n-d, z-g-l.

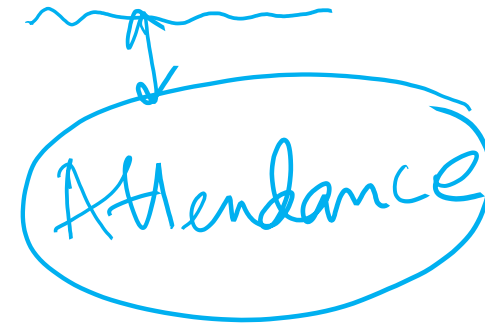
<https://lotr.fandom.com/wiki/Khuzdul>

[Khuzdul | The One Wiki to Rule Them All | Fandom - LOTR Wiki](#)

About Featured Snippets Feedback

Logistics: Zoom

- Online lectures for entire semester
- Save Internet traffic
 - Please mute your microphones
 - Turn off videos
- All questions primarily via chat
 - To be answered in two ~15 min slots:
immediately after break, immediately after class
 - Interactive QA experimentally
- Use headset if you want to speak
- Connect to LAN if possible instead of WiFi
- Switch off other Internet-hogging stuff during class
- Use laptop/desktop instead of mobile
- Slides and recordings (?) after lecture



Logistics : Course

- Research course, no textbook
- Roughly two (long) research papers discussed in lectures every week
- 1 ▪ Influential work in community
- 2 ▪ Work from our group: qa.mpi-inf.mpg.de ← link
- One written assignment per week (more on next slide)
- One toy coding assignment at the end
- Overlaps with IRDM last lecture ☺
- Teaching assistant: [Magdalena Kaiser](#)



Assignment

- 10 sentences on each paper
 - 1 ▪ 4-sentence summary
 - 2 ▪ 3 positives (one sentence each)
 - 3 ▪ 3 negatives (one sentence each)
- review
- 10 sentences x 2 papers = 20 sentences per week
 - plain In text file: 2020-qa-<your-name>-week-01.txt as attachment
 - Email to me and Magdalena with subject: 2020 QA Assignment Week 01/02/...
 - Deadline: Before start of next class

firstname-lastname
john-smith
aishwarya-pkumar

consistent

mention
im
id


Assignment (2)

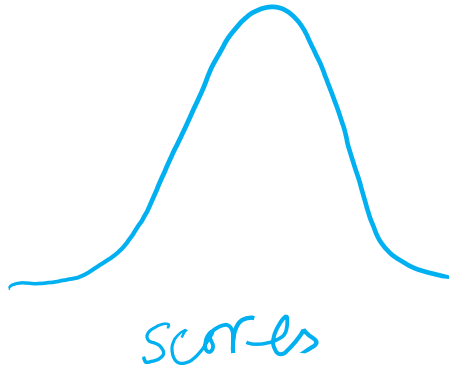
how?

- Contribute to final grade
- ✓ ▪ No right or wrong answers, or appropriate length
- Goal is to reduce arbitrariness in final exam
- No presentation of assignments necessary
- Clear cases of plagiarism will result in de-registration
- Estimate of hours per week
 - 2 hours lecture
 - 2 x ~2 hours reading two papers and commenting
 - 6 hours in all ~ 6 ECTS ☺

no group work

Exam

- 1 oral main exam
 - Tuesday 21 July 2020
 - 10 – 15 minutes per person
 - Depends on number of students
- 1 oral re-exam
 - Tuesday 28 July 2020? 
 - Tentative
- No re-re-exam ☺ ...



Lecture topics

- Template-based QA

- Curated KGs
- Open KGs
- Textual sources

- Named entity disambiguation (NERD)

- Neural methods for QA

- KG-QA
- Text-QA

What do we cover?

- Graph-based QA

- The IBM Watson system

- QA over heterogeneous sources

- Efficient QA systems

- Reinforcement learning in QA

- Conversational QA

- ...

semester → cut short
↓ 1 mark

x ?

11 lectures

~~Prerequisites~~ Background for QA?

- ✓ ■ Information retrieval
- ✓ ■ Natural language processing
- ✓ ■ Machine learning / DM
- ✓ ■ Database systems
- adef. { ■ Probability and statistics
- Linear algebra
- Optimization

→ RDM

Motivation

Question Answering: Vital for Search

What are some films directed
by Nolan?

Question Answering: Vital for Search

What are some films directed
by Nolan?

Christopher Nolan / Films directed



The Dark Knight
2008



Interstellar
2014

Question Answering: Vital for Search

What are some films directed by Nolan?

Christopher Nolan / Films directed

- Direct answers to questions
- Saves time and effort
- Natural in voice UI
- Relies on knowledge graphs



The Dark Knight
2008



Interstellar
2014

Question Answering: Vital for Search

What are the Oscar nominations
of Nolan?

Question Answering: Vital for Search

What are the Oscar nominations
of Nolan?

Christopher Nolan Academy
Awards Awards / Awards

Best Picture

2018 · Dunkirk

Best Director

2018 · Dunkirk

Best Picture

2011 · Inception

Best Original Screenplay

2011 · Inception

Question Answering: Vital for Search

What are the Oscar nominations
of Nolan?

Which Oscar nominations did
Nolan receive?

Question Answering: Diversity?

What are the Oscar nominations of Nolan?

Which Oscar nominations did Nolan receive?

Here's what I found

diff



But for all that, he had only three Oscar nominations. He was nominated for writing "Memento" in 2002, and received writing and best picture nominations for 2010's "Inception." "Dunkirk" is tied with "Inception" and

Question Answering: Diversity?

What are the Oscar nominations
of Nolan?

Which Oscar nominations did
Nolan receive?

What are the Cannes award
nominations of Ryan Coogler?

Question Answering: Diversity?

What are the Oscar nominations of Nolan?

Which Oscar nominations did Nolan receive?

What are the Cannes award nominations of Ryan Coogler?

Here's what I found

[Ryan Coogler - Awards - IMDb](#)

[https://m.imdb.com > name > awards](https://m.imdb.com/name/awards)

Ryan Coogler on IMDb: **Awards, nominations, and wins.** ... Fruitvale Station (2013). **Cannes Film...**

Challenges in QA systems

- Diversity in question formulation
 - Works only for specific entities and formulations
 - Cannot understand syntax and generalize
 - Cannot capture semantic equivalence

Question Answering is a hot topic

- QA over knowledge graphs [Abujabal et al. 2018]
- Reading comprehension QA [Reddy et al. 2018]
- Visual and multimodal QA [Lu et al. 2016]
- Community QA [Hoogeveen et al. 2018]
- Passage retrieval and sentence selection [Shen et al. 2018]
- Non-factoid: Causal, procedural, ...

factoid

research
↓
IR, NLP, AI

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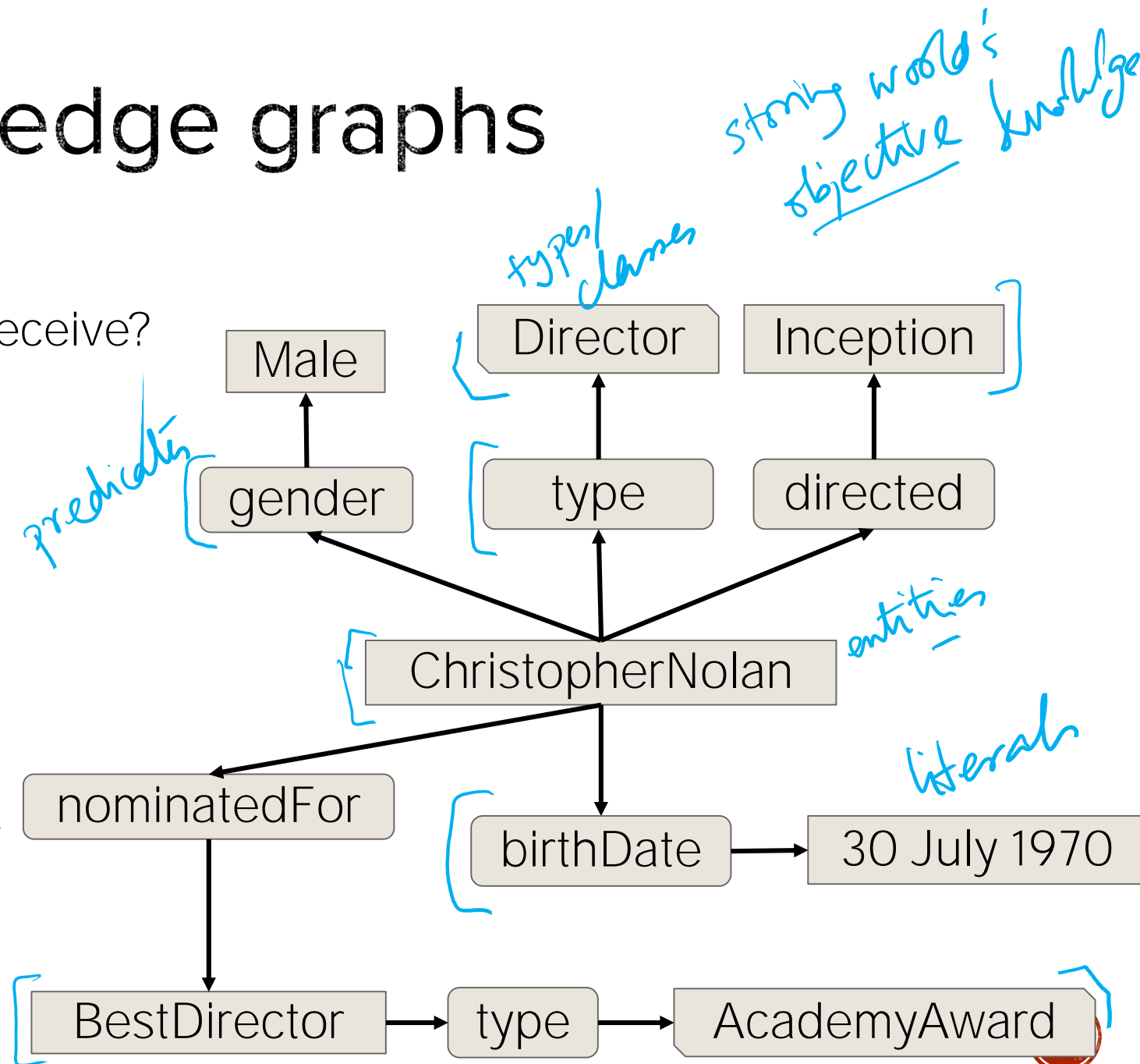
QA over knowledge graphs

Which Oscar nominations did Nolan receive?

QA over knowledge graphs

Which Oscar nominations did Nolan receive?

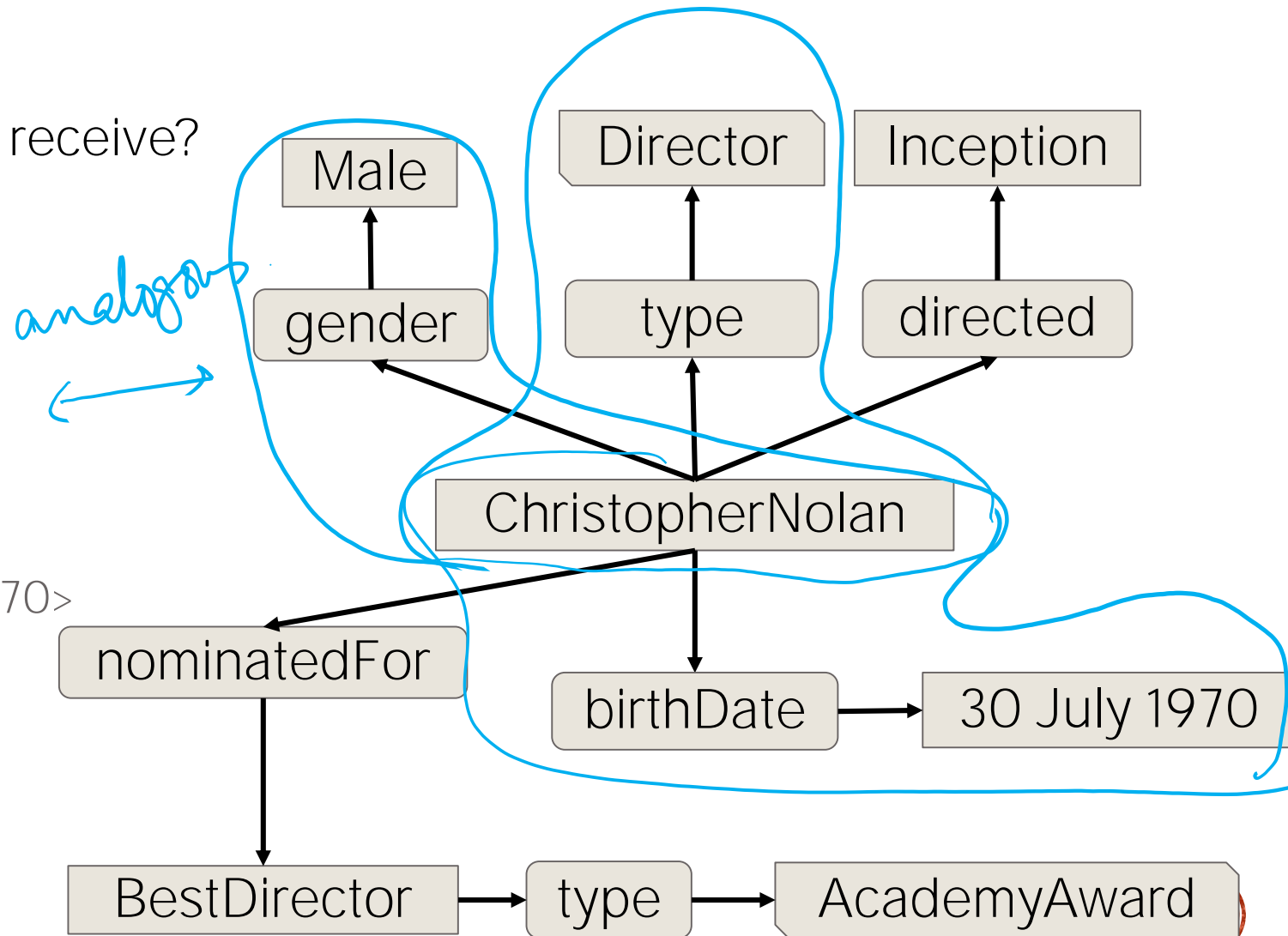
- 1 YAGO [Suchanek et al. 2007]
- 2 DBPedia [Auer et al. 2007]
- 3 Freebase [Bollacker et al. 2008]
- 4 Wikidata [Vrandečić and Krötzsch 2014]



QA over knowledge graphs

Which Oscar nominations did Nolan receive?

→ <ChristopherNolan, gender, Male>
<ChristopherNolan, type, Director>
<ChristopherNolan, directed, Inception>
<ChristopherNolan, nominatedFor, BestDirector>
<BestDirector, type, AcademyAward>
<ChristopherNolan, birthDate, 30 July 1970>



QA over knowledge graphs

problem 1

mapping / alignment

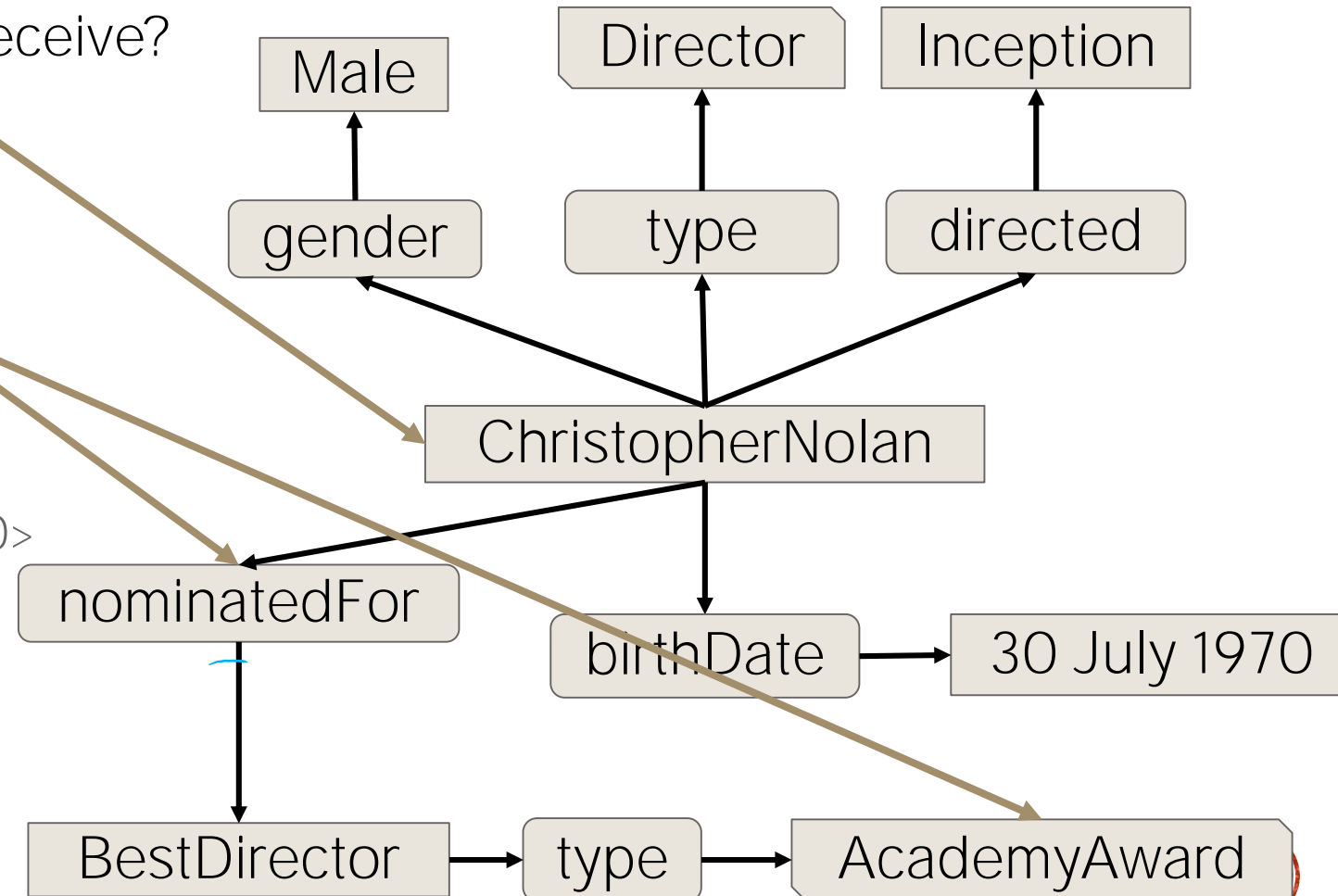
Which Oscar nominations did Nolan receive?

RDF

dump / triplestore

<ChristopherNolan, gender, Male>
<ChristopherNolan, type, Director>
<ChristopherNolan, directed, Inception>
<ChristopherNolan, nominatedFor, BestDirector>
<BestDirector, type, AcademyAward>
<ChristopherNolan, birthDate, 30 July 1970>

> 1B triples → fact

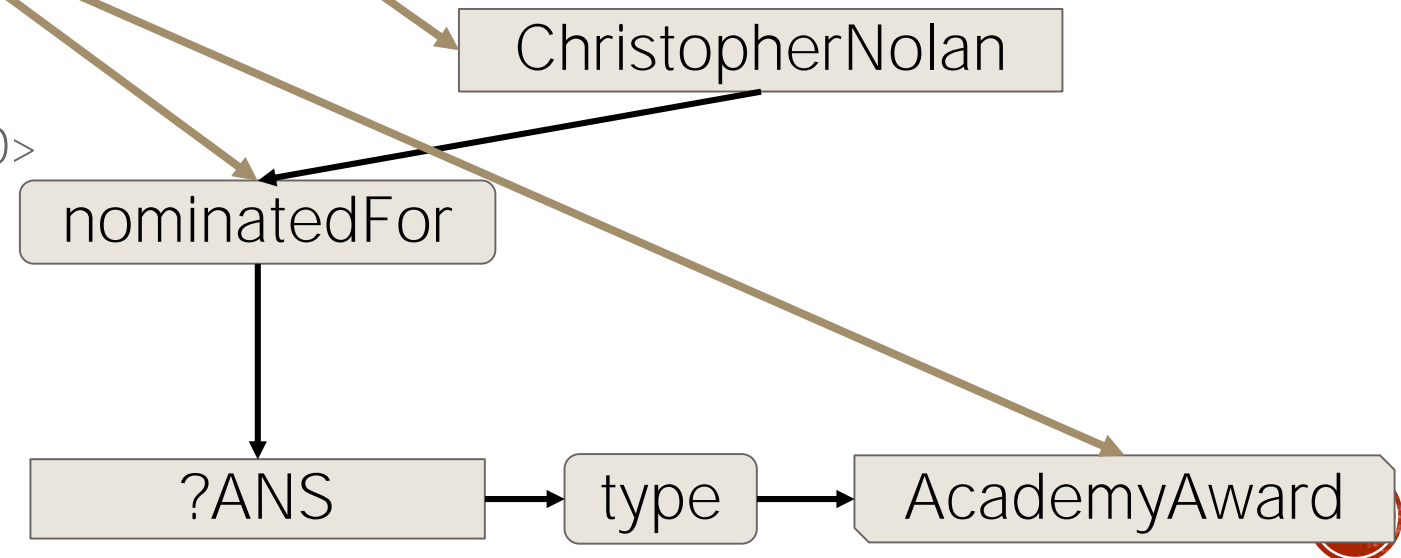


QA over knowledge graphs

problem 2

Which Oscar nominations did Nolan receive?

<ChristopherNolan, gender, Male>
<ChristopherNolan, type, Director>
<ChristopherNolan, directed, Inception>
<ChristopherNolan, nominatedFor, BestDirector>
<BestDirector, type, AcademyAward>
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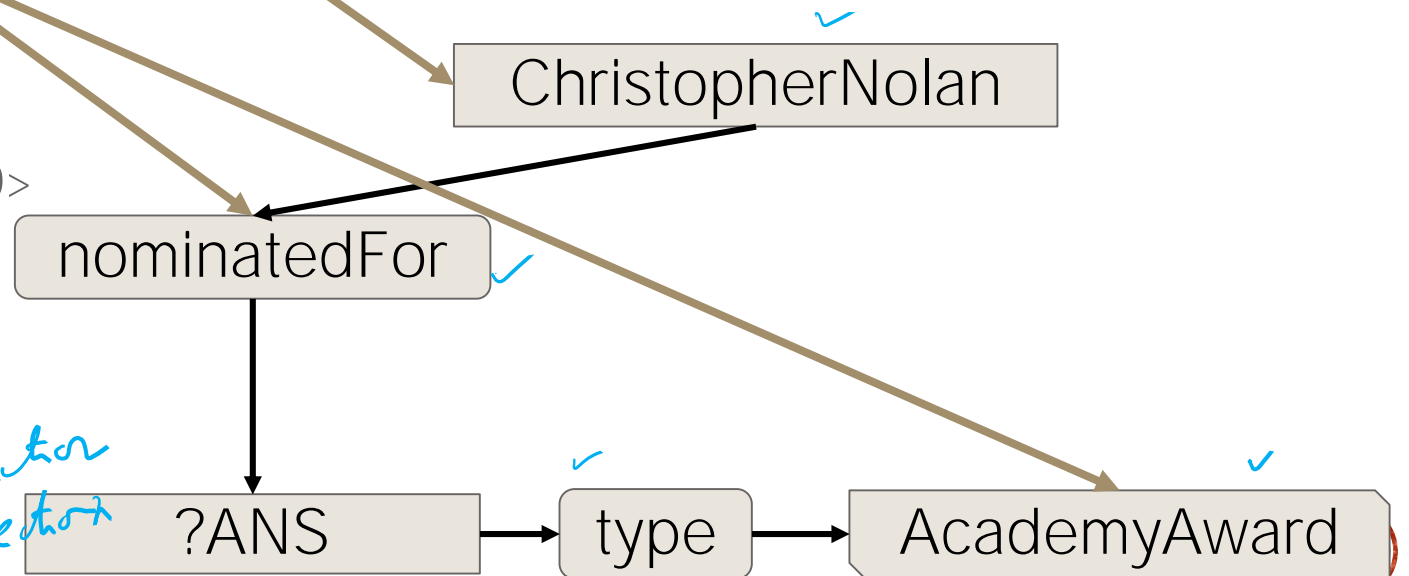
QA over knowledge graphs

Which Oscar nominations did Nolan receive?

<ChristopherNolan, gender, Male>
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<BestDirector, type, AcademyAward>
<ChristopherNolan, birthDate, 30 July 1970>

✓ SELECT ?ANS
✓ WHERE {
ChristopherNolan nominatedFor ?ANS
?ANS type AcademyAward }
- conjunction interest

SPARQL



QA over knowledge graphs

surface forms / lexical units → question

Which Oscar nominations did Nolan receive?

S P O

- <ChristopherNolan, gender, Male>
- <ChristopherNolan, type, Director>
- <ChristopherNolan, directed, Inception>
- <ChristopherNolan, nominatedFor, BestDirector>
- <BestDirector, type, AcademyAward>
- <ChristopherNolan, birthDate, 30 July 1970>

SELECT ?ANS
WHERE {
ChristopherNolan nominatedFor ?ANS .
?ANS type AcademyAward }

BestDirector

SPARQL

nominatedFor

?ANS

type

AcademyAward

ChristopherNolan

(SPARQL) query

*logical form
and semantic denotation*

semantic units / KG concepts

Explore knowledge graphs + SPARQL

- Wikidata: https://www.wikidata.org/wiki/Wikidata:Main_Page

~ Wikipedia

- <https://www.wikidata.org/wiki/Q8877>

← Steven Spielberg

- Wikidata SPARQL Endpoint: <https://query.wikidata.org/>

```
SELECT ?subject ?subjectLabel ?predicateLabel ?object ?objectLabel ?qualifierLabel ?qualifierObject ?qualifierObjectLabel {  
  VALUES (?subject) {(wd:Q8877) }  
  
  ?subject ?p ?statement .  
  ?statement ?ps ?object .  
  
  ?predicate wikibase:claim ?p.  
  ?predicate wikibase:statementProperty ?ps.  
  
  OPTIONAL{ ?statement ?pq ?qualifierObject . ?qualifier wikibase:qualifier ?pq .}  
  
  SERVICE wikibase:label { bd:serviceParam wikibase:language "en" } }
```

SS → subject
S P O

Question of the day

How can we use templates for answering questions over knowledge graphs?

Tackling language diversity

syntax

semantics

- If we can answer:

- What are the Oscar award nominations of Nolan?

- Then we should be able to answer:

- What are the Cannes award nominations of Ryan Coogler?
- Which Oscar award nominations did Nolan receive?

Same syntax!

Same semantics!

Tackling language diversity

- If we can answer:
 - What are the Oscar award nominations of Nolan?
- Then we should be able to answer:
 - What are the Cannes award nominations of Ryan Coogler?

first
Same syntax!

Template-based question answering

① ✓ Interpretable

Question Who is <u>Inception</u> 's <u>director</u> ?	Question template Who is <NOUN1>'s <NOUN2>?
Query ?ANS <u>director</u> Inception	Query template ?ANS <PRED1> <ENT1>

Handwritten annotations:
- Blue dashed arrows connect "Inception" to "<NOUN1>" and "director" to "<NOUN2>".
- A blue arrow points from "Inception" to "Inception" in the query.
- A blue arrow points from "director" to "<PRED1>".
- A blue arrow points from "<ENT1>" to "Inception".
- A blue arrow points from "<NOUN2>" to "slot".
- A blue arrow points from "slot" to "<ENT1>".
- A blue arrow points from "executive on KG" to "Inception".
- A box on the right contains the text "1 SPARQL triple pattern" with a checkmark and underlines.

Template-based question answering

- ② ▪ Generalizes to new domains

Who is Libya's president?
Who is Messi's manager?

Politics
Football

Question Who is Inception's director?	Question template Who is <NOUN1>'s <NOUN2>?
Query ?ANS director Inception	Query template ?ANS <PRED1> <ENT1>

movie

1 SPARQL
triple pattern

Template-based question answering

- Generalizes to new domains

Question Who plays the role of Cobb in Inception?	Question template Who <VERB> <DT> <NOUN> <PREP> <NOUN>?
Query ?ANS playsIn Inception ?ANS role Cobb	Query template ?ANS <PRED1> <ENT1> ?ANS <PRED2> <ENT2>

2 SPARQL
triple patterns

You'll find this covered in

1. Template-based Question Answering over RDF Data

- Unger et al., 2012
- The Web Conference (previously WWW)
- https://pub.uni-bielefeld.de/download/2495397/2526223/template-based_question.pdf

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

- Abujabal et al., 2018
- The Web Conference (previously WWW)
- <https://myahya.org/publications/neqa-abujabal-www2018.pdf>

Research paper 1

Template-based Question Answering over RDF Data

Template-based Question Answering over RDF Data

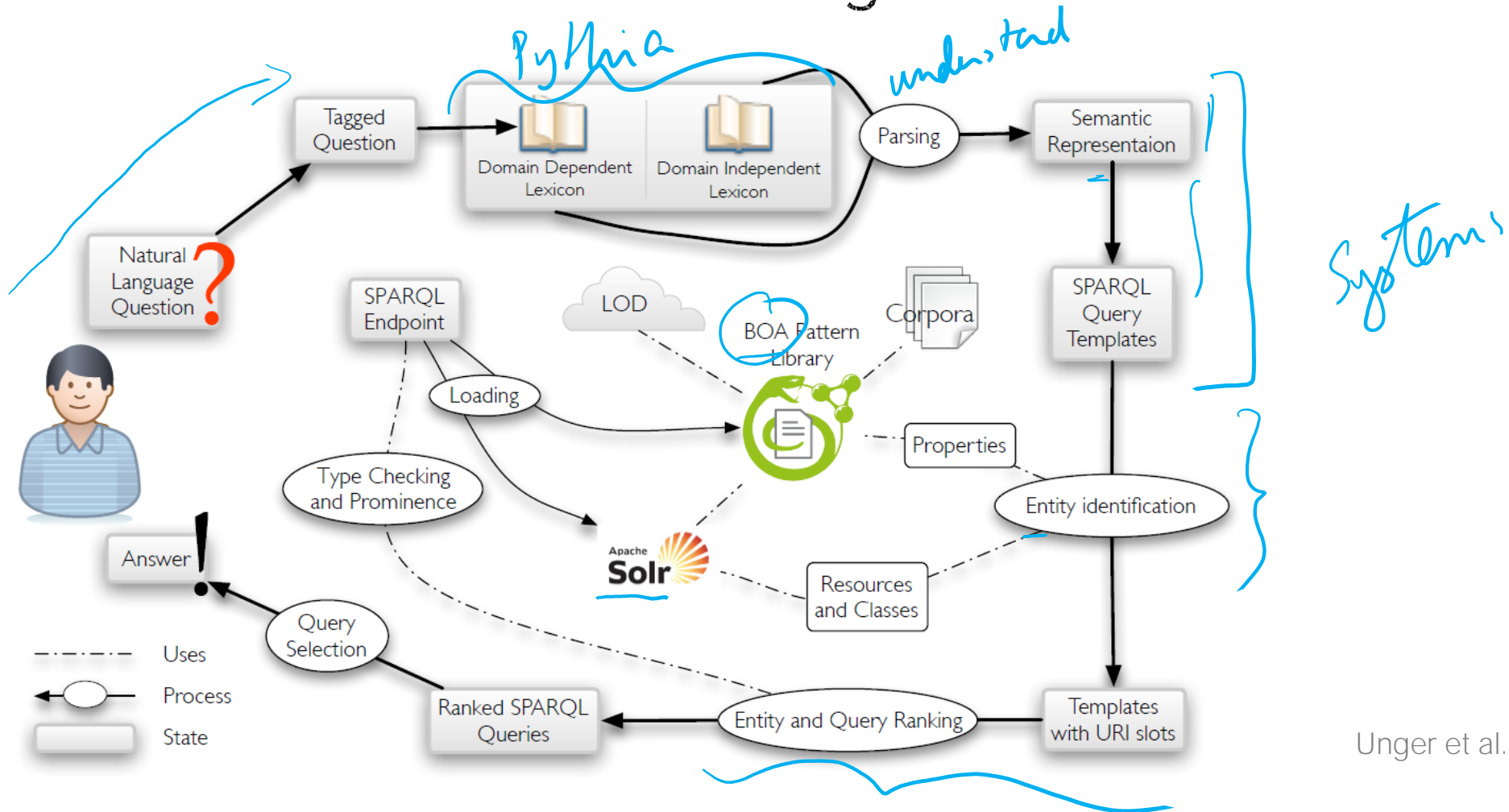


Figure 1: Overview of the template based SPARQL query generator.

Template-based Question Answering over RDF Data

1. Template generation
ent, pred, class today

2. Entity identification

3. Query ranking and selection

*instantiate
template*

*resource
↓
entity today*

- Q 1. (a) Which cities have more than three universities?
(b) $\langle [\text{cities}], \text{more than}, \text{universities three} \rangle$
(c) `SELECT ?y WHERE {`

```
    ?x rdf:type onto:University .  
    ?x onto:city ?y .  
}  
HAVING (COUNT(?x) > 3)
```

- Q 2. (a) Who produced the most films?
(b) $\langle [\text{person}, \text{organization}], \text{produced}, \text{most films} \rangle$
(c) `SELECT ?y WHERE {
 ?x rdf:type onto:Film .
 ?x onto:producer ?y .
}
ORDER BY DESC(COUNT(?x)) OFFSET 0 LIMIT 1`

Template-based Question Answering over RDF Data

- Template generation
- Entity identification
- Query ranking and selection

3. SELECT ?x WHERE {
 ?x ?p ?y .
 ?y rdf:type ?c .
}
ORDER BY DESC(COUNT(?y)) LIMIT 1 OFFSET 0

template

p = predicate
c = class

Template-based Question Answering over RDF Data

- Template generation
- Entity identification
- Query ranking and selection

Template generation

- SPARQL templates
- Constructing SPARQL templates

4. How many films did Leonardo DiCaprio star in?

(a) SELECT COUNT(?y) WHERE {
 ?y rdf:type ?c .
 ?x ?p ?y .
}

filter (pointing to the WHERE clause)
query structure (pointing to the entire query)

Slots:

- <?x, resource, Leonardo DiCaprio> *entity*
- <?c, class, films>
- <?p, property, star> *predicate*

(b) SELECT COUNT(?y) WHERE {
 ?x ?p ?y .
}

Slots:

- <?x, resource, Leonardo DiCaprio>
- <?p, property, films>

relation (pointing to the property slot in (b))
query structure (pointing to the entire query)
KG (Knowledge Graph, pointing to the query)

Template generation

- SPARQL templates
- Constructing SPARQL templates

5. (a) who/WP produced/VBD the/DT most/JJS
films/NNS

(b) Covered tokens: who, the most, the, most , *where*

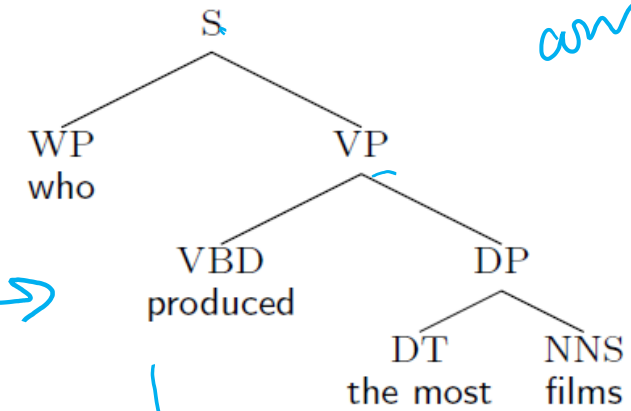
(c) Building entries for: produced/VBD, films/NNS

• domain-independent (vocabulary)
 domain-specific ()

Pudlik / Stanford

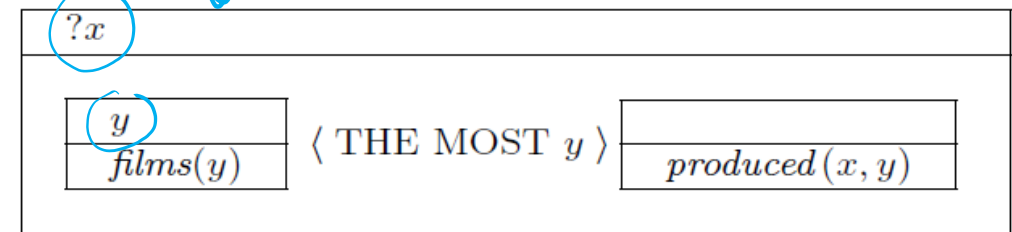
parser

6.



construction tree

7.



Template generation

template
handcrafted
→ experts

- SPARQL templates
- Constructing SPARQL templates

leaves (person)
noun → entity
verb → predicate
married → spouse of
not always true
wife of

8. (a) `SELECT ?x WHERE {
 ?x ?p ?y .
 ?y rdf:type ?c .
}`
`ORDER BY DESC(COUNT(?y)) LIMIT 1 OFFSET 0`
Slots:

- `<?c, class, films>`
- `<?p, property, produced>`

(b) `SELECT ?x WHERE {
 ?x ?p ?y .
}`
`ORDER BY DESC(COUNT(?y)) LIMIT 1 OFFSET 0`
Slots:

- `<?p, property, films>`

Entity identification

- Generic approach
 - Synonyms
 - Similarity functions

ent, pred, class
KG concepts

[film
[movie
bridge bioscope
this vocabulary gap

$$E(s) = \arg \max_{s' \in S(s)} \sigma(s', \text{label}(e))$$

Entity identification

Property detection

- 1 Support *norm freq*
- 2 Typicity
- 3 Specificity *= IDF*

pattern mining for
~ Wikipedia

BOA

type signature of predicate (L+R & pred)

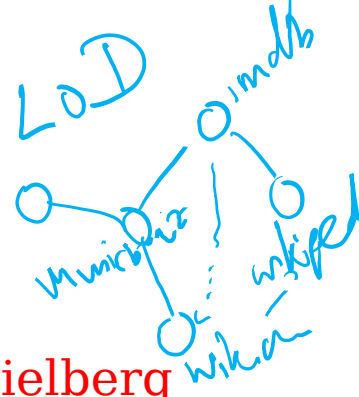
leader of
President
Chancellor
PPM

$$c(\theta, p) = \text{sup}(\theta, p) \cdot \text{typ}(\theta, p) \cdot \text{spec}(\theta)$$

StevenSpielberg sibling AnneSpielberg

StevenSpielberg has a sister named AnneSpielberg

detect paraphrase → paraphrase



dictionary lexicon (table)

surface form	K G for + score
sister	sibling
sister name	sibling
brother	sibling.

Query ranking and selection

- We now have entities to fill template slots
- Many possible queries
- Queries need to be executed, best used
- ¹ Similarity and ² prominence scores of slot values (entities)
 $\Rightarrow \psi(e)$
- Score of query = average of scores of slot values
 - + Type checker
 - + Non-empty, non-zero result-queries only

$$\text{score}(e) = \alpha \cdot \max(\psi(\cdot)) + (1-\alpha) \psi(e)$$

execute a large nos.
post-hoc
→ best guess →
Ans

Research paper 2

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

Limitations of templates

- Hand-crafted by experts (Fader et al. 2014; Unger et al. 2013)
- Low coverage

Limitations of templates

- Hand-crafted by experts (Fader et al. 2014; Unger et al. ²⁰¹²~~2013~~)
- Low coverage
- Solution: Learn templates

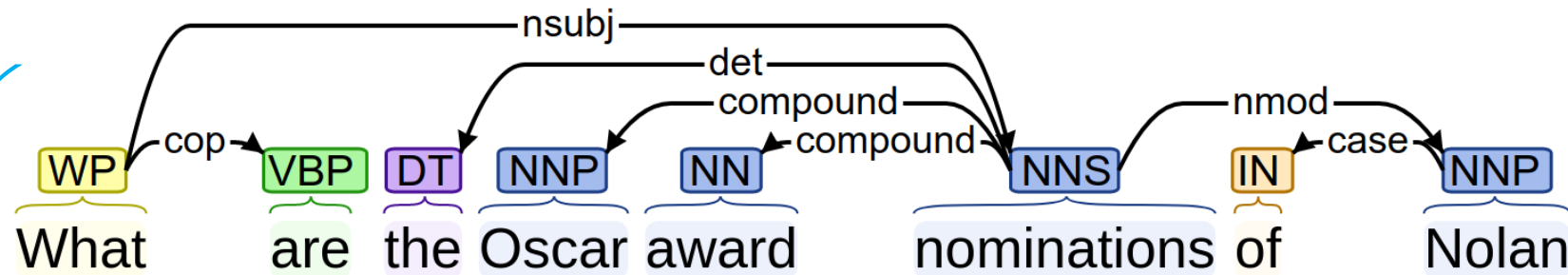
Limitations of templates

- Hand-crafted by experts (Fader et al. 2014; Unger et al. 2013)
- Low coverage
- Solution: Learn templates
 - 1 ▪ Question templates
 - 2 ▪ Query templates
 - 3 ▪ Slot alignments

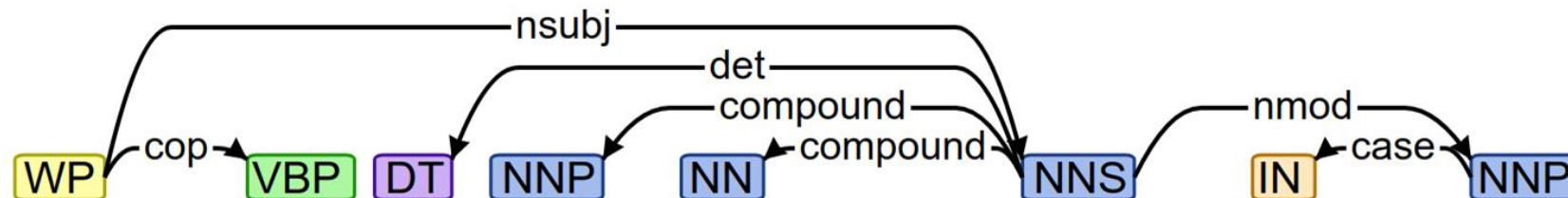
Extend to graphical question templates

Question: What are the Oscar award nominations of Nolan?

Dependency parse



Question template (labeled nodes and edges)



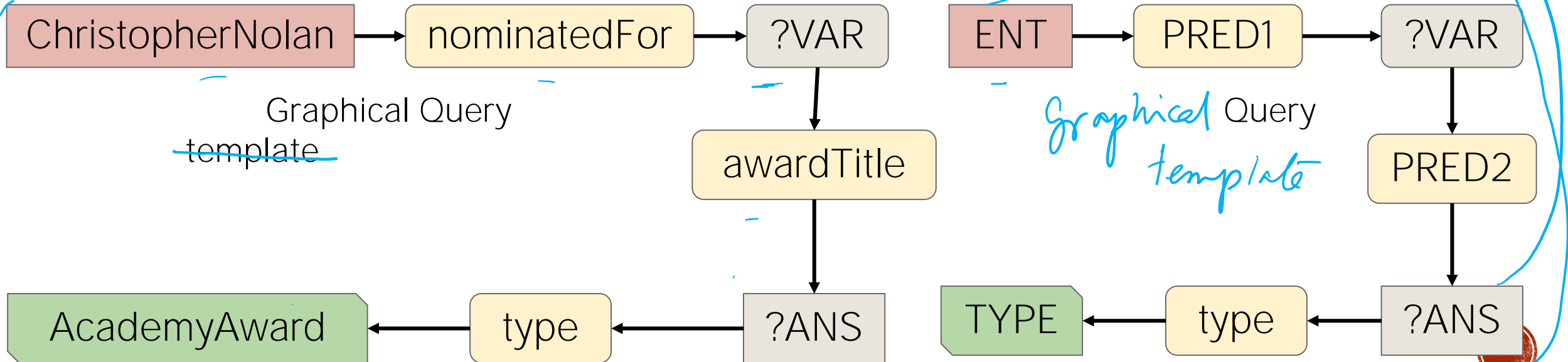
Graphical query templates

Query:

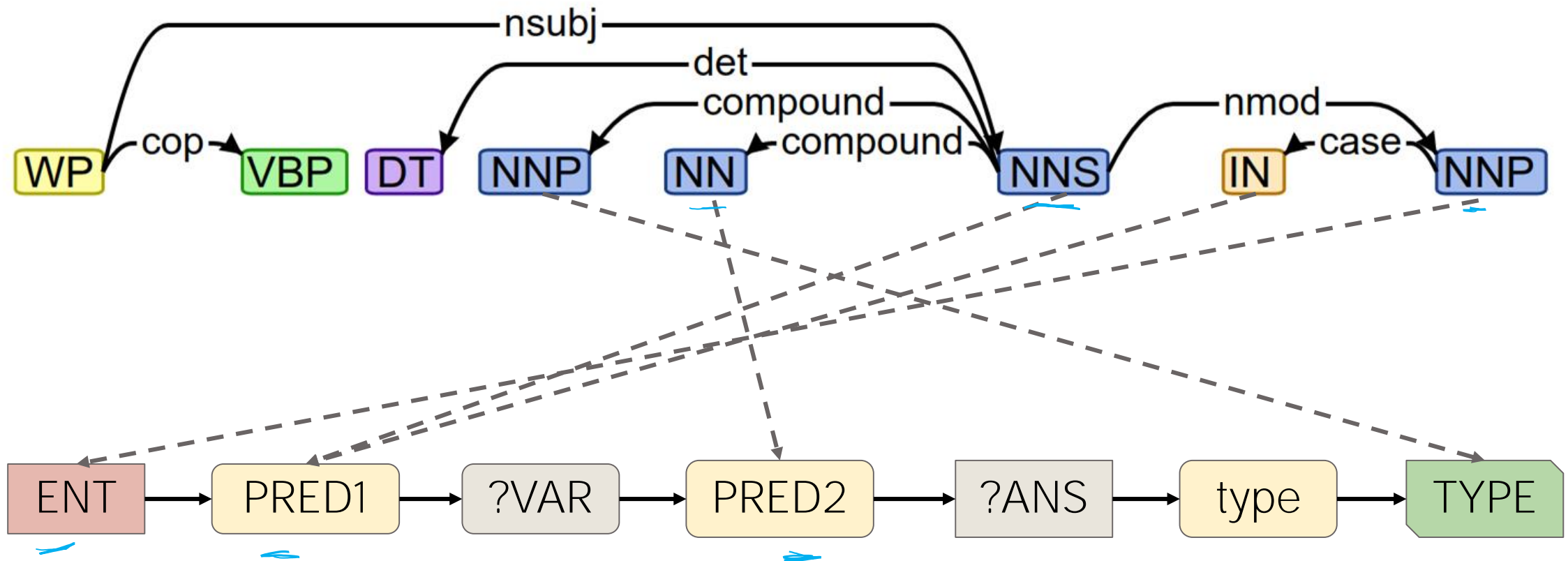
ChristopherNolan nominatedFor ?VAR .

?VAR awardTitle ?ANS .

?ANS type AcademyAward

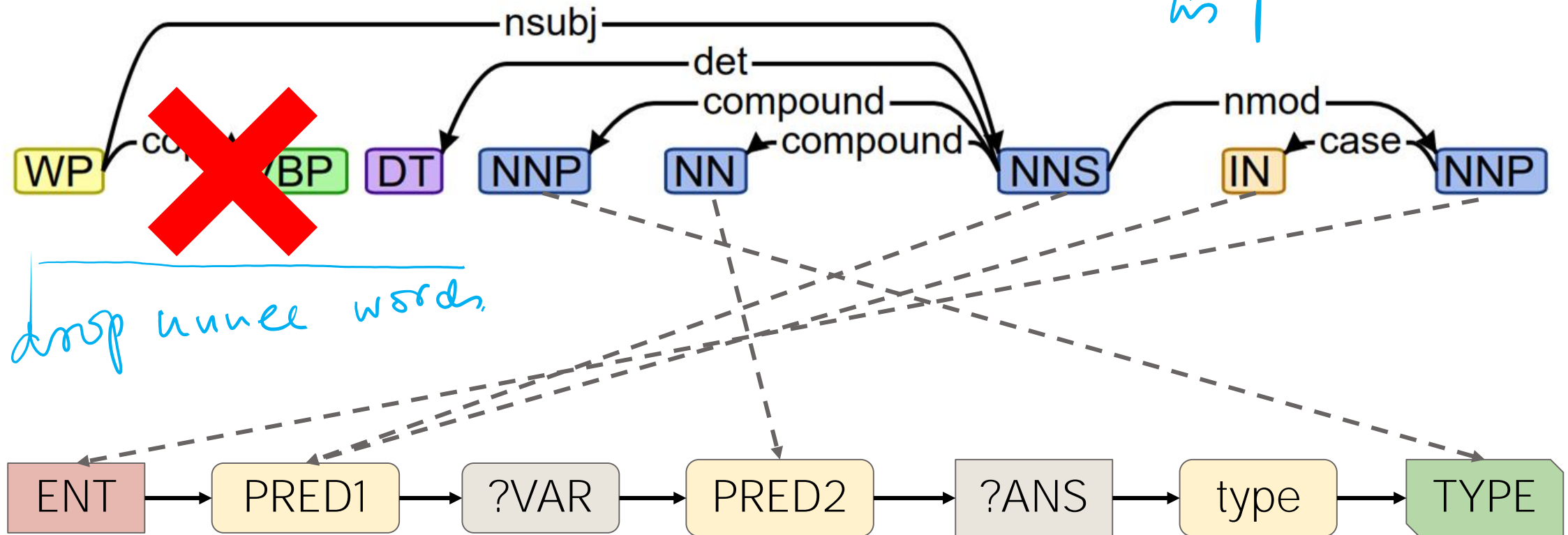


Slot alignments *mapping*

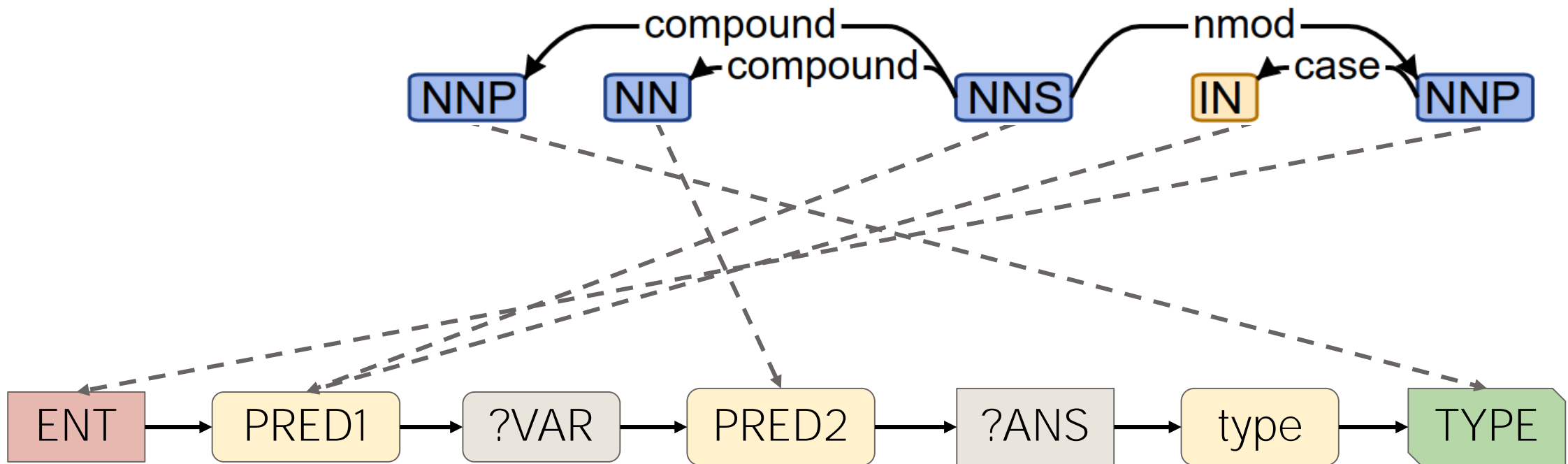


Slot alignments

as generalizable
as possible



✓ Slot alignments



Tackling diversity: Our 5-point agenda

1. Start small with seed training data
2. Learn syntactic templates on-the-fly
3. Extend coverage with semantic similarity *of templates*
4. User feedback to prevent erroneous learning
5. Assimilate into continuous learning framework *for layer*

✓ NEQA: Never-ending Learning for Question Answering