Provenance for Natural Language Queries

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Presented by Amir Gilad

Outline

Motivation

NL Query

Return the organization of authors who published papers in database conferences after 2005

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Return the organization of authors who published papers in database conferences after 2005

Formal Query

```
query(oname) :- org(oid, oname), conf(cid, cname),
pub(wid, cid, ptitle, pyear), author(aid, aname, oid),
domainConf(cid, did), domain(did, dname),

writes(aid, wid), dname = 'Databases', pyear > 2005
```

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Result

Tel Aviv University (TAU)

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Result

Tel Aviv University (TAU) (why?)

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writes(aid, wid), dname = 'Databases', pyear > 2005
```

What We Have - Provenance

```
(oname,TAU)·(aname,Tova M.)·(ptitle,OASSIS...)·(cname,SIGMOD)·(pyear,14')+
(oname,TAU)·(aname,Tova M.)·(ptitle,Querying...)·(cname,VLDB)·(pyear,06')+
(oname,TAU)·(aname,Tova M.)· (ptitle,Monitoring...)·(cname,VLDB)·(pyear,07')+
(oname,TAU)·(aname,Slava N.)·(ptitle,OASSIS...)·(cname,SIGMOD)·(pyear,14')+
(oname,TAU)·(aname,Tova M.)·(ptitle,A sample...)·(cname,SIGMOD)·(pyear,14')+
...
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```

What We Want - Explanations

TAU is the organization of 43 authors who published 170 papers in 31 conferences in 2006 - 2015

Solution Overview

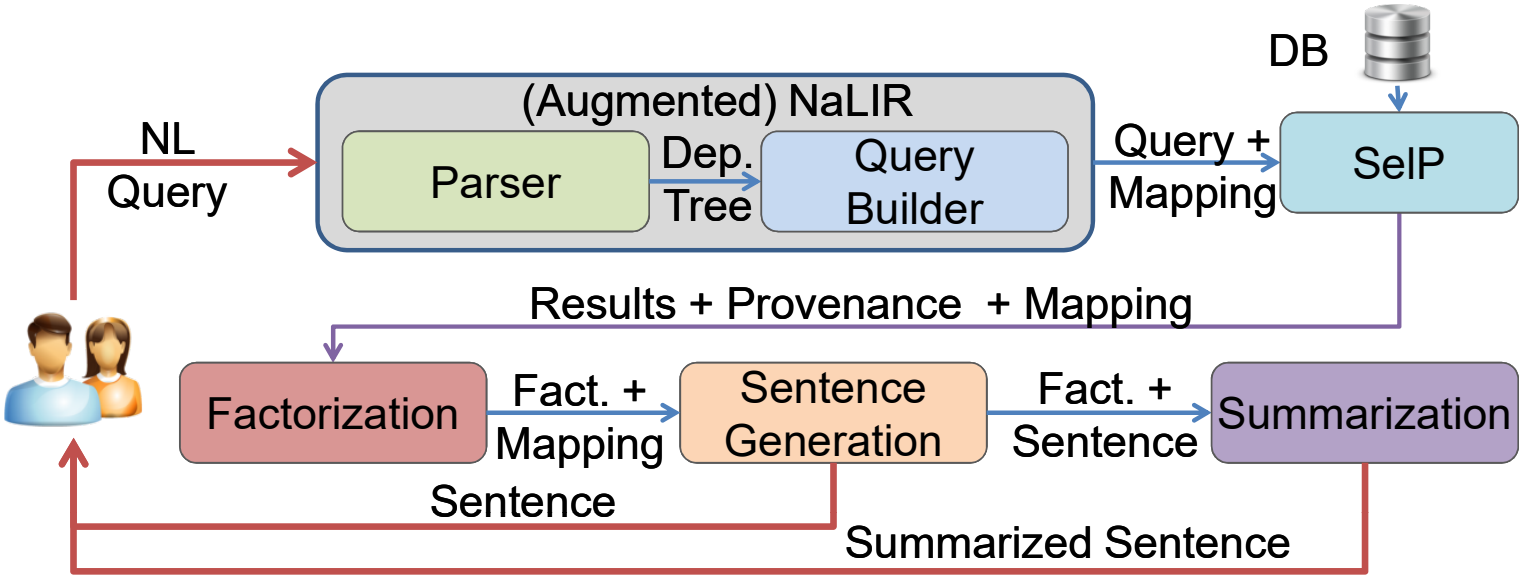
Solution

- Use the input question to formulate a detailed NL answer by replacing words with values
  - This is a general idea: showing provenance in a way that corresponds to the standard user interaction
- When a long answer is needed, compact it using algebraic factorization and summarization
  - Here, again, we leverage the structure of the user question

Current Limitations

- Only conjunctive queries are supported
- Some aspects of the solution are limited to a specific NLIDB
  - But the general idea is not

Framework



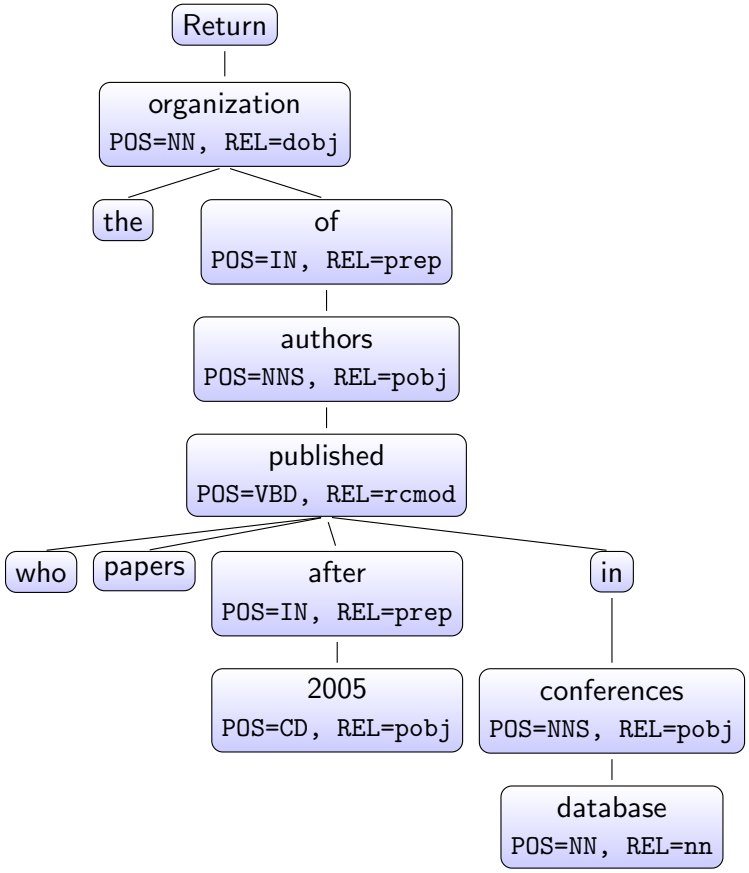
- Augment NaLIR [Fei Li, Jagadish, 15']
- Use a provenance-aware engine - SelP [Deutch et al., 15']
- Store the provenance and mappings
- Translate results and provenance to NL using factorization and summarization

Outline

Mappings

Return the organization of authors who published papers in database conferences after 2005

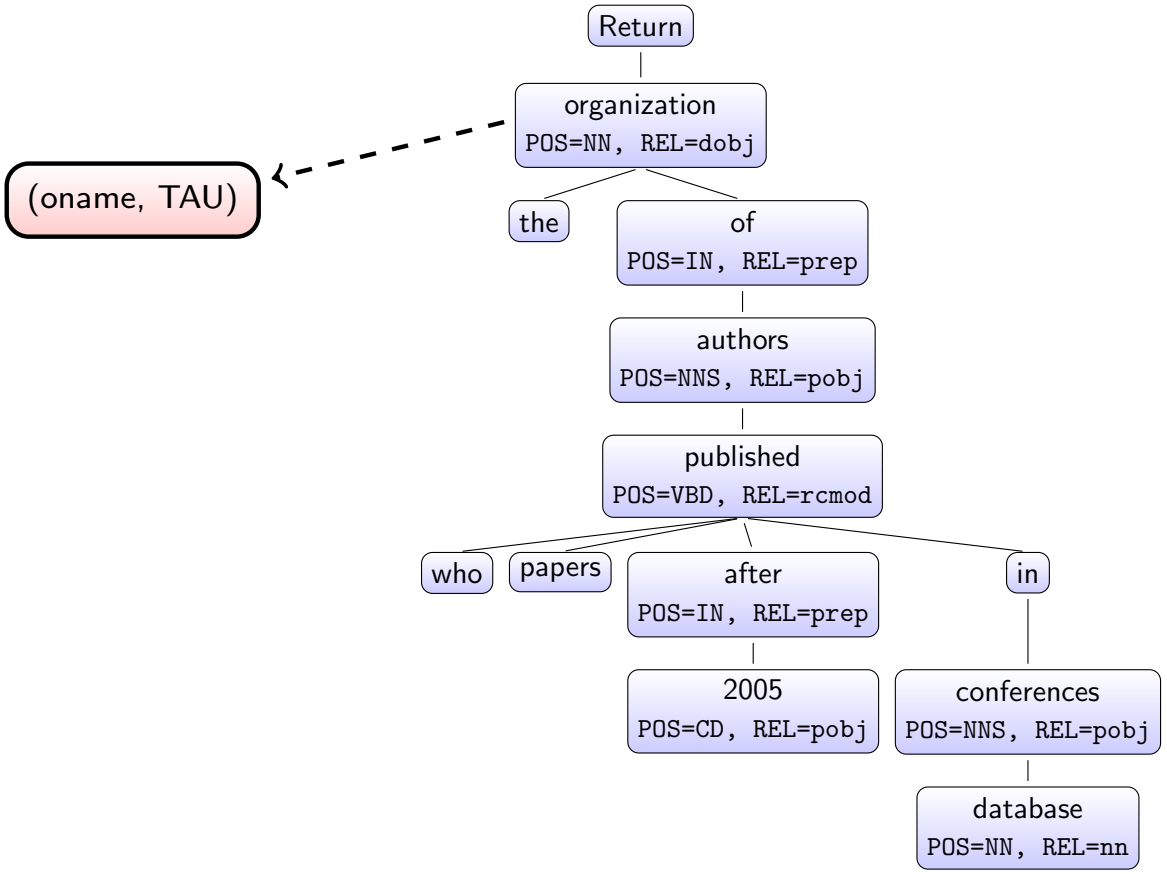
query(oname) :- org(oid, oname), conf(cid, cname), pub(wid, cid, ptitle, pyear), author(aid, aname, oid), domainConf(cid, did), domain(did, dname), writes(aid, wid), dname = 'Databases', pyear > 2005



Mappings

Return the **organization** *of authors who published papers in database conferences after 2005*

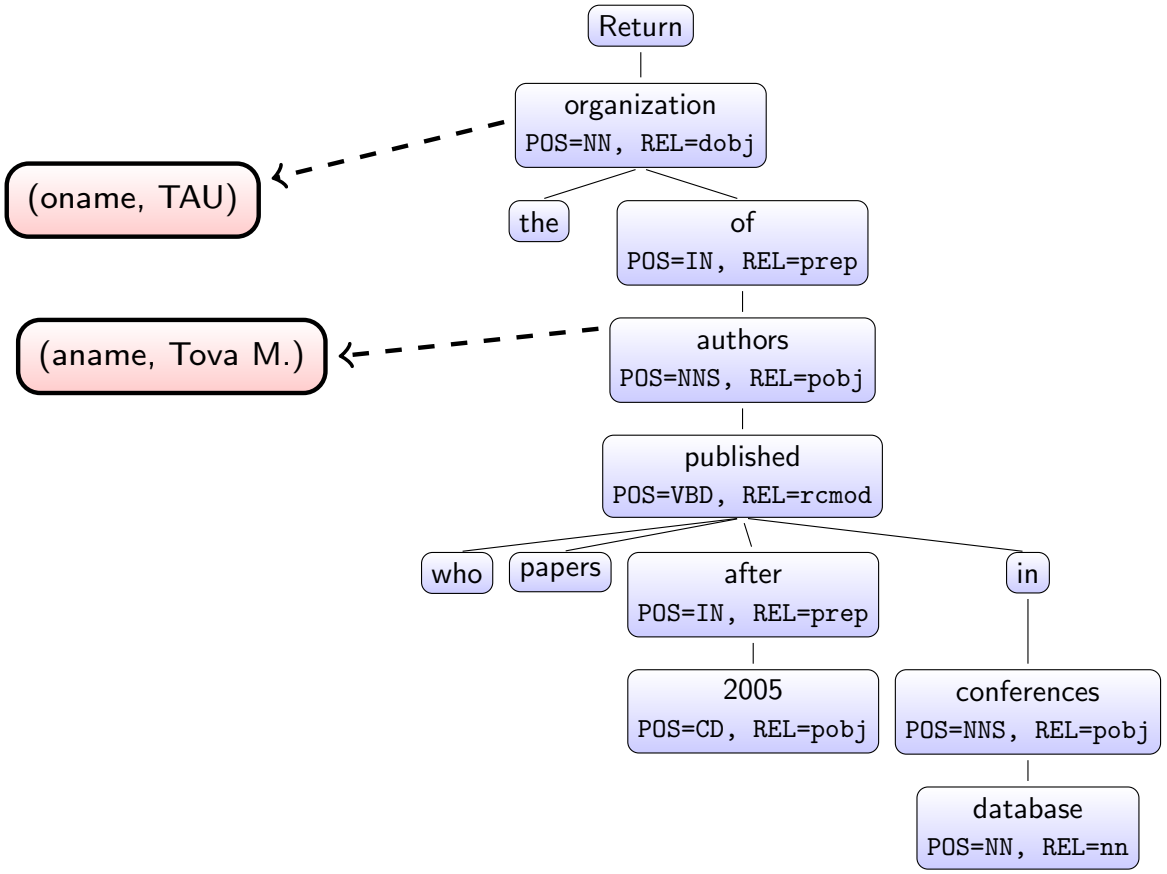
*query(***oname***) :- org(oid,* ***oname****), conf(cid, cname), pub(wid, cid, ptitle, pyear), author(aid, aname, oid), domainConf(cid, did), domain(did, dname), writes(aid, wid), dname = 'Databases', pyear > 2005*



Mappings

Return the organization of **authors** *who published papers in database conferences after 2005*

query(oname) :- org(oid, oname), conf(cid, cname), pub(wid, cid, ptitle, pyear), author(aid, **aname**, *oid), domainConf(cid, did), domain(did, dname), writes(aid, wid), dname = 'Databases', pyear > 2005*



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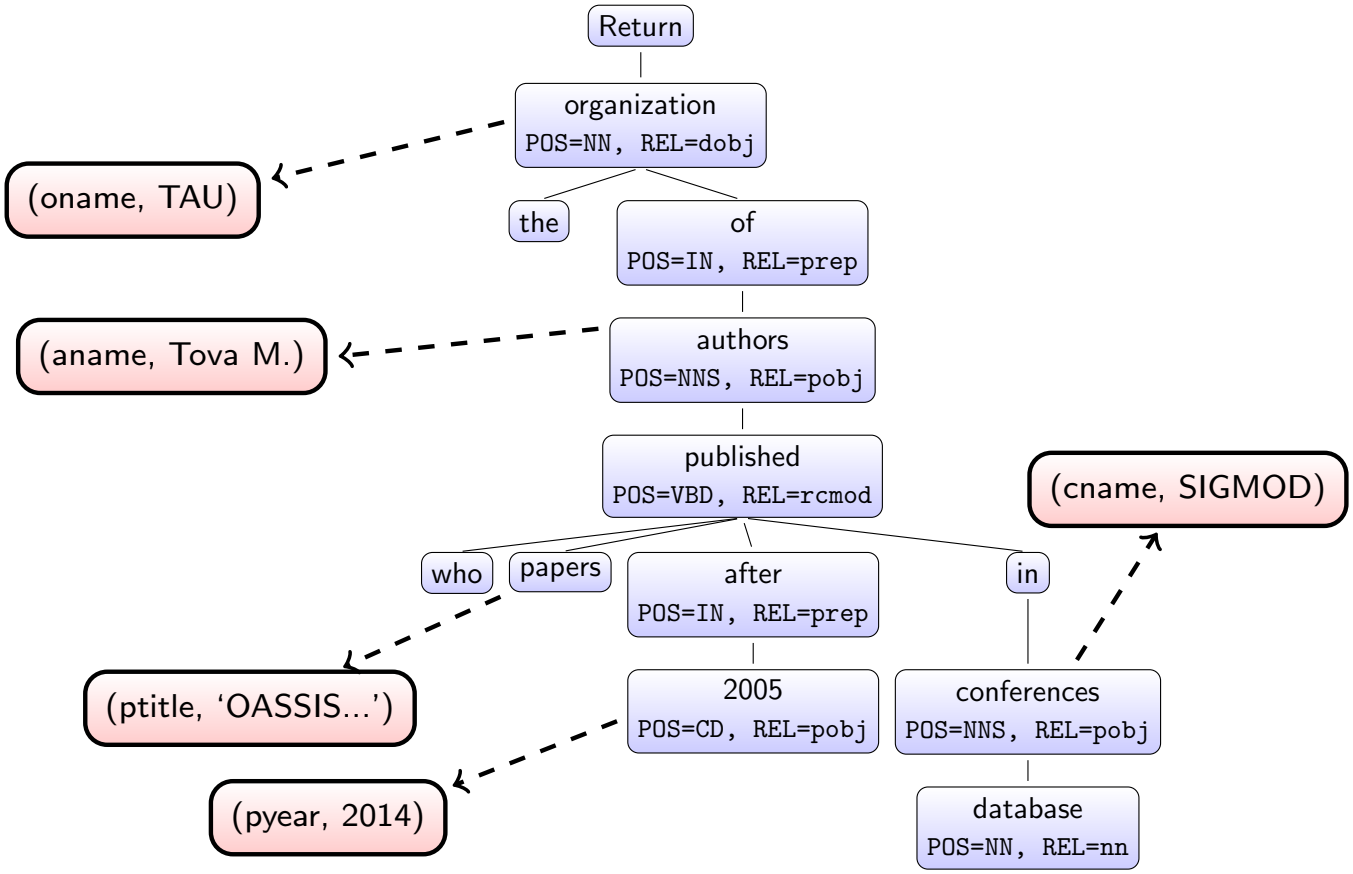
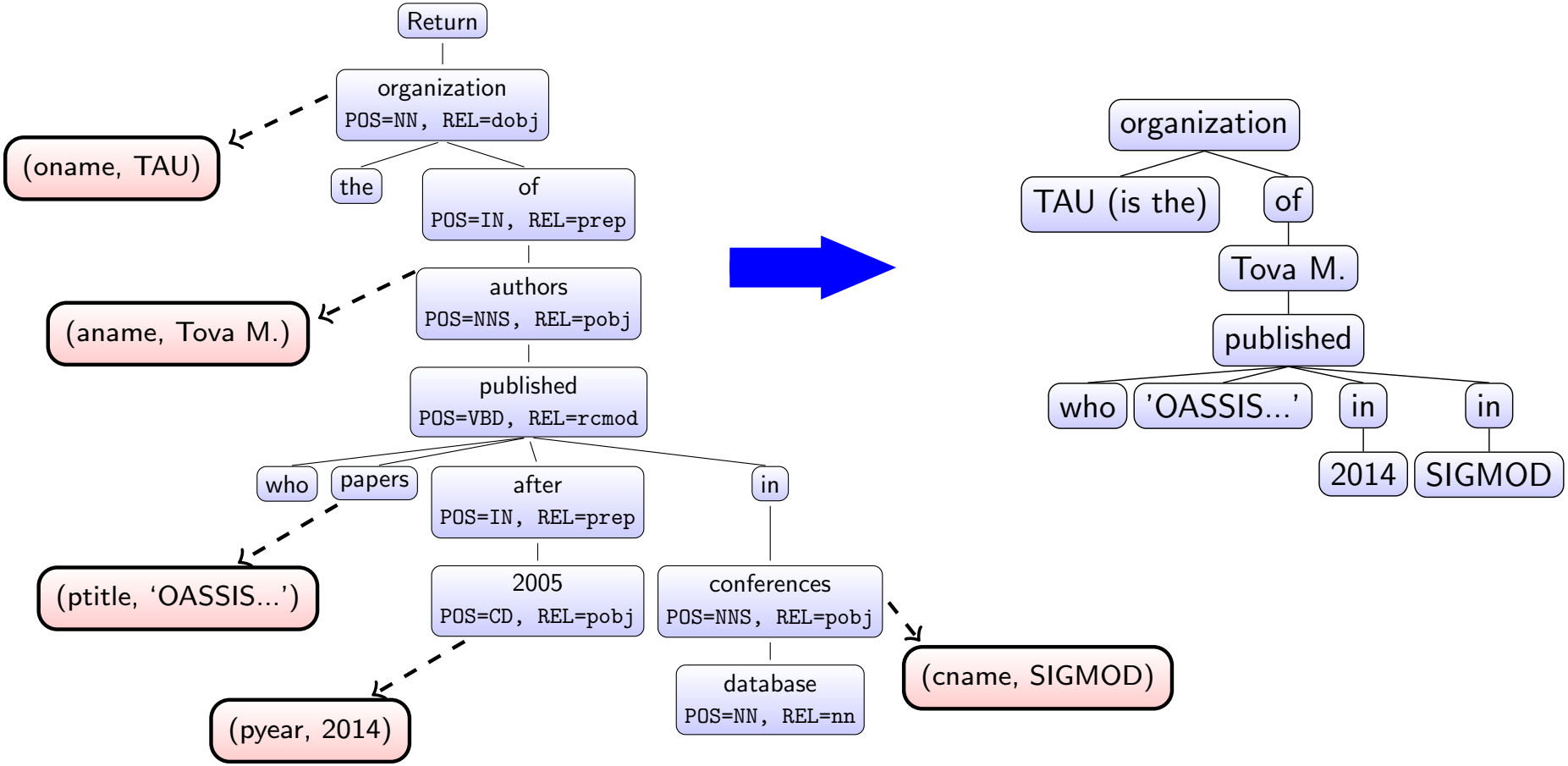
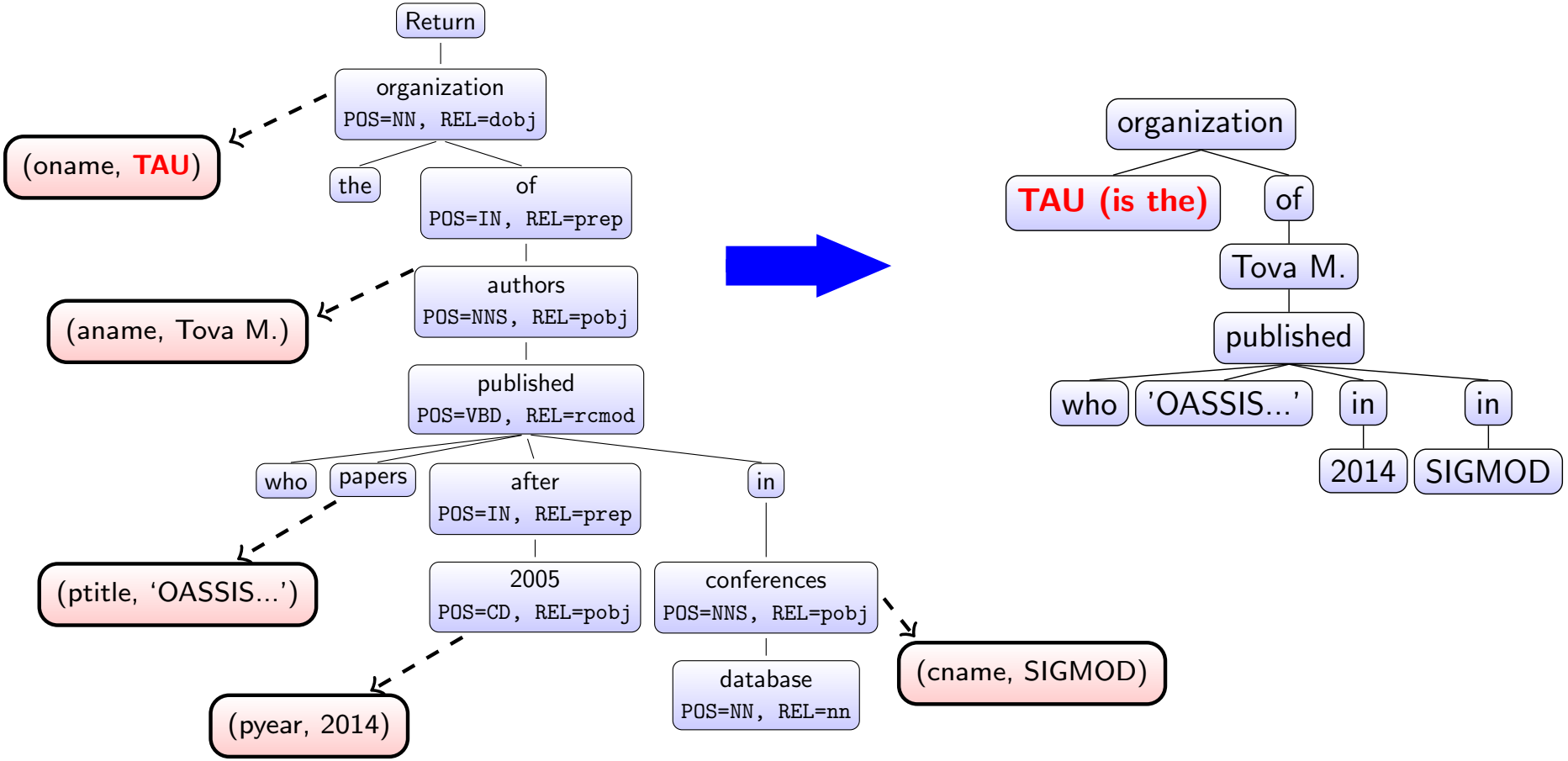


From Mappings to an Answer



From Mappings to an Answer



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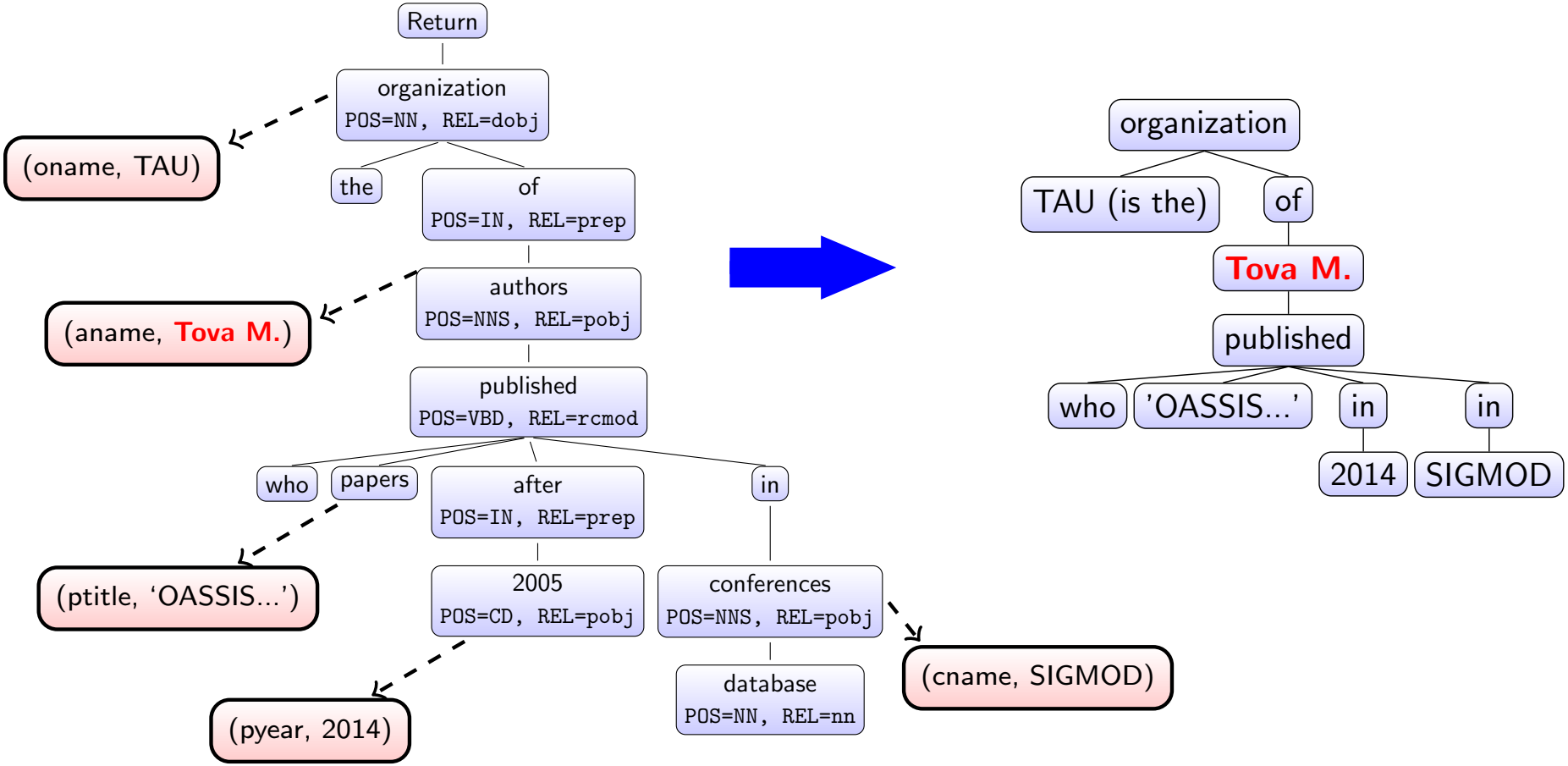

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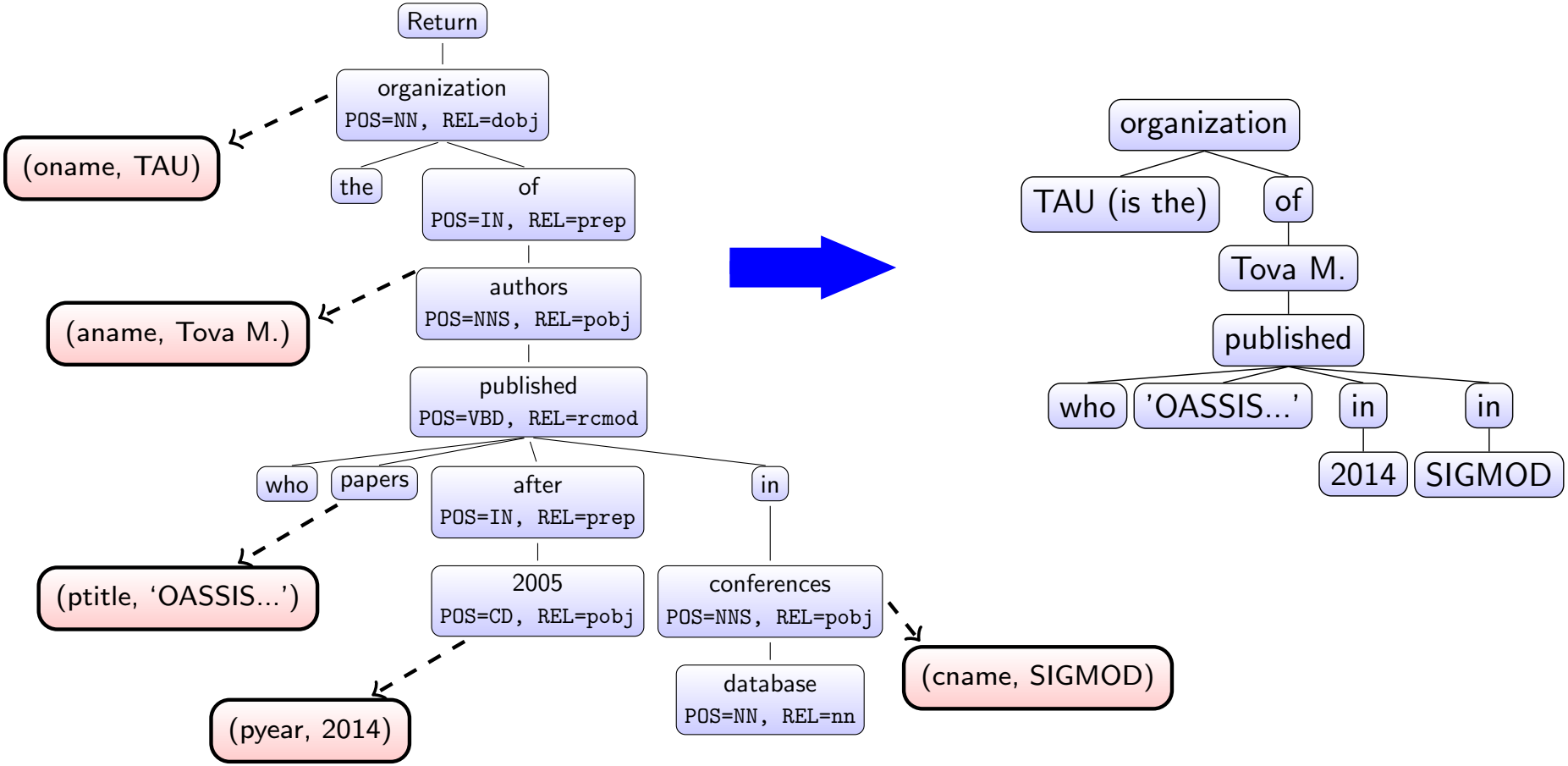

Answer

TAU is the organization of Tova M. who published 'OASSIS...' in SIGMOD in 2014

Outline

Provenance Factorization

Idea

- Use algebraic factorization of the provenance to take-out common values that appear in multiple assignments

Provenance

```
[TAU]·[Tova M.]·[OASSIS...]·[SIGMOD]·[2014]+
[TAU]·[Tova M.]·[Querying...]·[VLDB]·[2006]+
[TAU]·[Tova M.]· [Monitoring..]·[VLDB]·[2007]+
[TAU]·[Slava N.]·[OASSIS...]·[SIGMOD]·[2014]+
[TAU]·[Tova M.]·[A sample...]·[SIGMOD]·[2014]
```

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```

Two Different Factorizations

```
[TAU] ·
 ([SIGMOD] · [2014] ·
 ([OASSIS...] ·
 ([Tova M.] + [Slava N.]))
  + [Tova M.] · [A Sample...])
  + [VLDB] · [Tova M.] ·
 ([2006] · [Querying...]
  + [2007] · [Monitoring...])
```

```
[TAU] ·
([Tova M.] ·
([VLDB] ·
 ([2006] · [Querying...]
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Provenance Factorization

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- Use algebraic factorization of the provenance to take-out common values that appear in multiple assignments

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[TAU]·[Tova M.]·[OASSIS...]·[SIGMOD]·[2014]+
[TAU]·[Tova M.]·[O...]·[VLDB]·[2006]+
[TAU]·[Tova M.]·[...]·[VLDB]·[2007]+
[TAU]·[Slava N.]...IGMOD]·[2014]+
[TAU]·[Tova M.]...SIGMOD]·[2014]
```

Shorter means better?

Two Different Factorizations

```
[TAU] ·
 ([SIGMOD] · [2014] ·
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  + [VLDB] · [Tova M.] ·
 ([2006] · [Querying...]
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[TAU] ·
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```

T-Compatibility

NL Query

Return the organization of authors who published papers in database conferences after 2005

Shortest Factorization

```
[TAU] ·
 ([SIGMOD] · [2014] ·
 ([OASSIS...] ·
 ([Tova M.] + [Slava N.]))
  + [Tova M.] · [A Sample...])
  + [VLDB] · [Tova M.] ·
 ([2006] · [Querying...]
  + [2007] · [Monitoring...])
```

As a Sentence

TAU is the organization **of authors who published in**
SIGMOD 2014
'OASSIS...' **which was published by**
Tova M. and Slava N.
and Tova M. published 'A sample...'
and Tova M. published in VLDB
'Querying...' in 2014
and 'Monitoring...' in 2007.

T-Compatibility

Shortest Factorization

```
[TAU] ·
 ([SIGMOD] · [2014] ·
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 ([Tova M.] + [Slava N.]))
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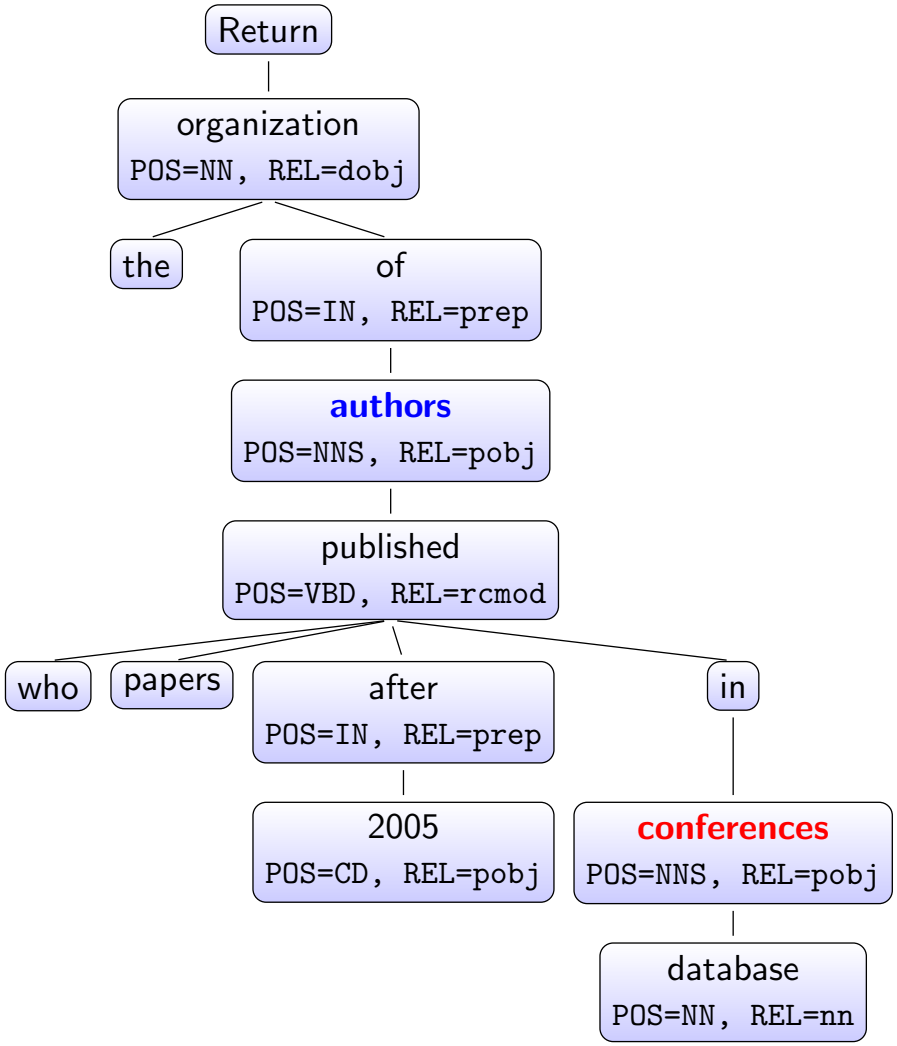

$conferences \leq_T authors$ but $conferences \not\leq_{f_{bad}} authors$

T-Compatibility

NL Query

Return the organization of authors who published papers in database conferences after 2005

Longer, T-Compatible Factorization

```
[TAU] ·
([Tova M.] ·
([VLDB] ·
 ([2006] · [Querying...]
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+ [SIGMOD] · [2014] ·
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As a Sentence

```
TAU is the organization of
 Tova M. who published
 in VLDB
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 and in SIGMOD in 2014
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Factorization Algorithm

Proposition

- Obtaining a minimal T-compatible factorization is coNP-hard

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Algorithm

- Factorize greedily: traverse the dependency tree level-by-level
- For every level with mapped words, factorize their corresponding values in the provenance
- Prioritize which values to take-out in each level by frequency

Factorization Algorithm

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- Obtaining a minimal T-compatible factorization is coNP-hard

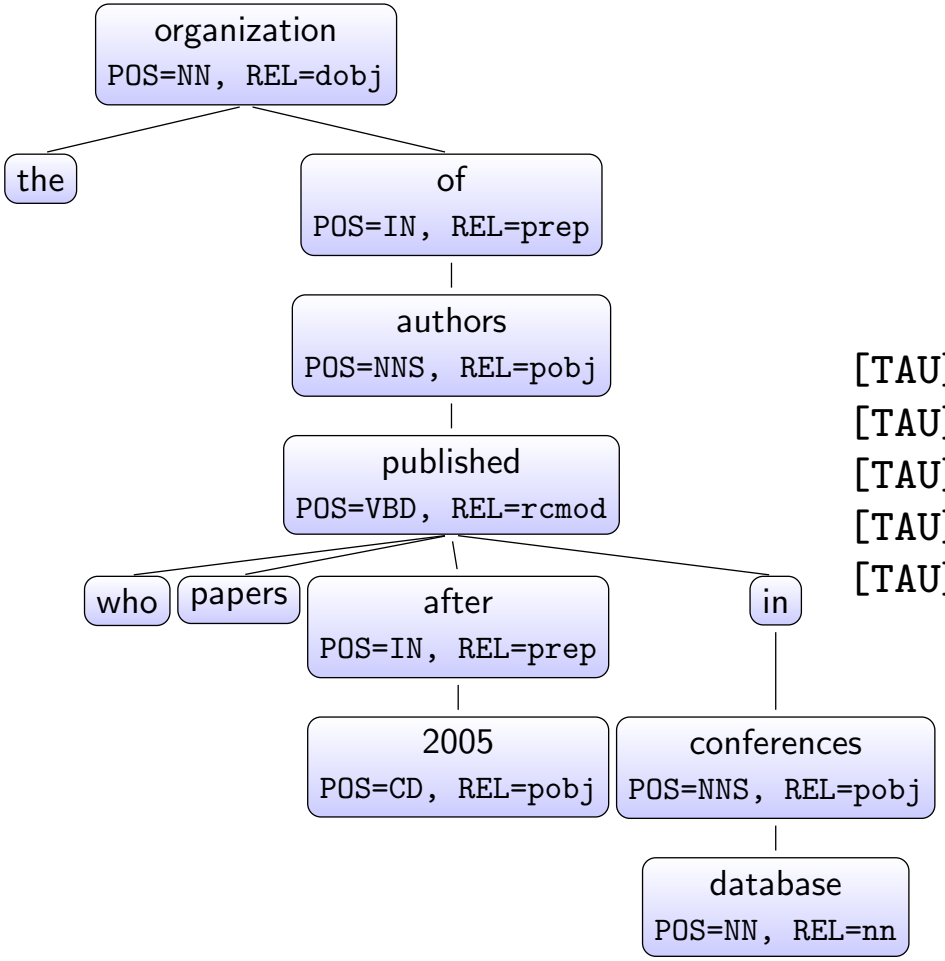
Algorithm

- Factorize greedily: traverse the dependency tree level-by-level
- For every level with mapped words, factorize their corresponding values in the provenance
- Prioritize which values to take-out in each level by frequency

Complexity

- $\mathcal{O}(n^2 \cdot \log n)$: recursively traverse the dependency tree and sort the variables at each layer by their frequency in $\mathcal{O}(n \cdot \log n)$

Factorization Example



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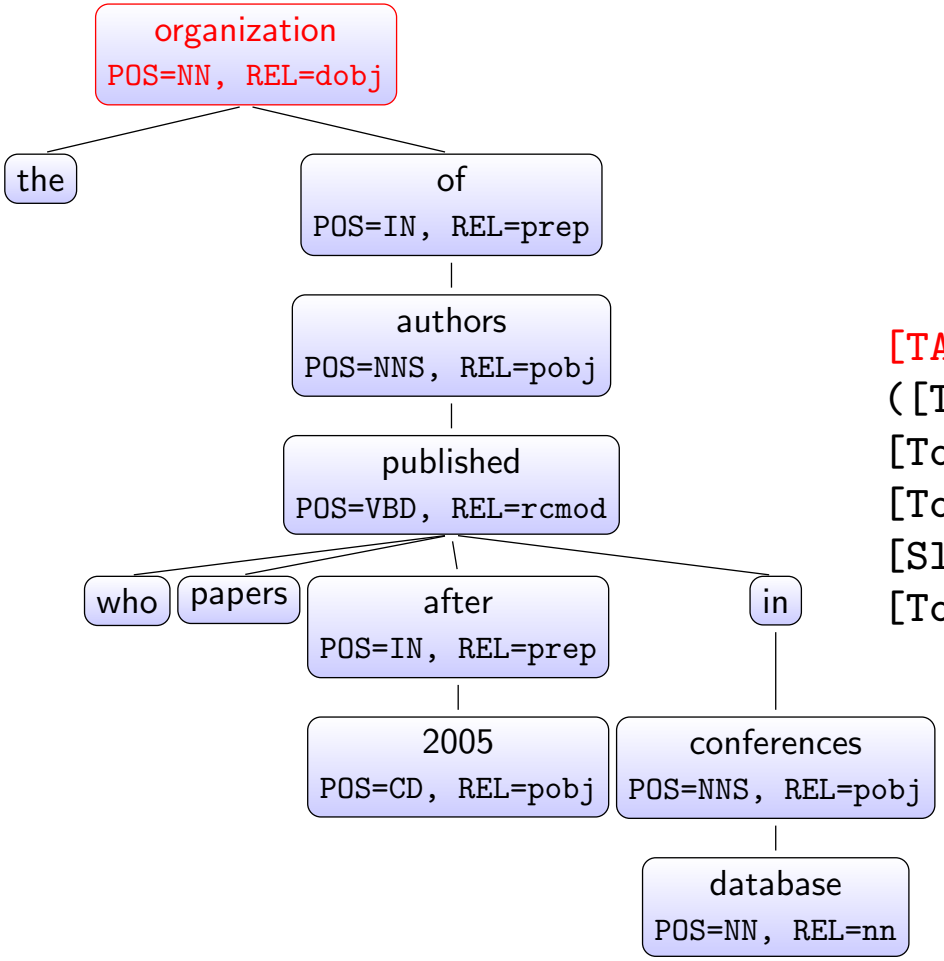

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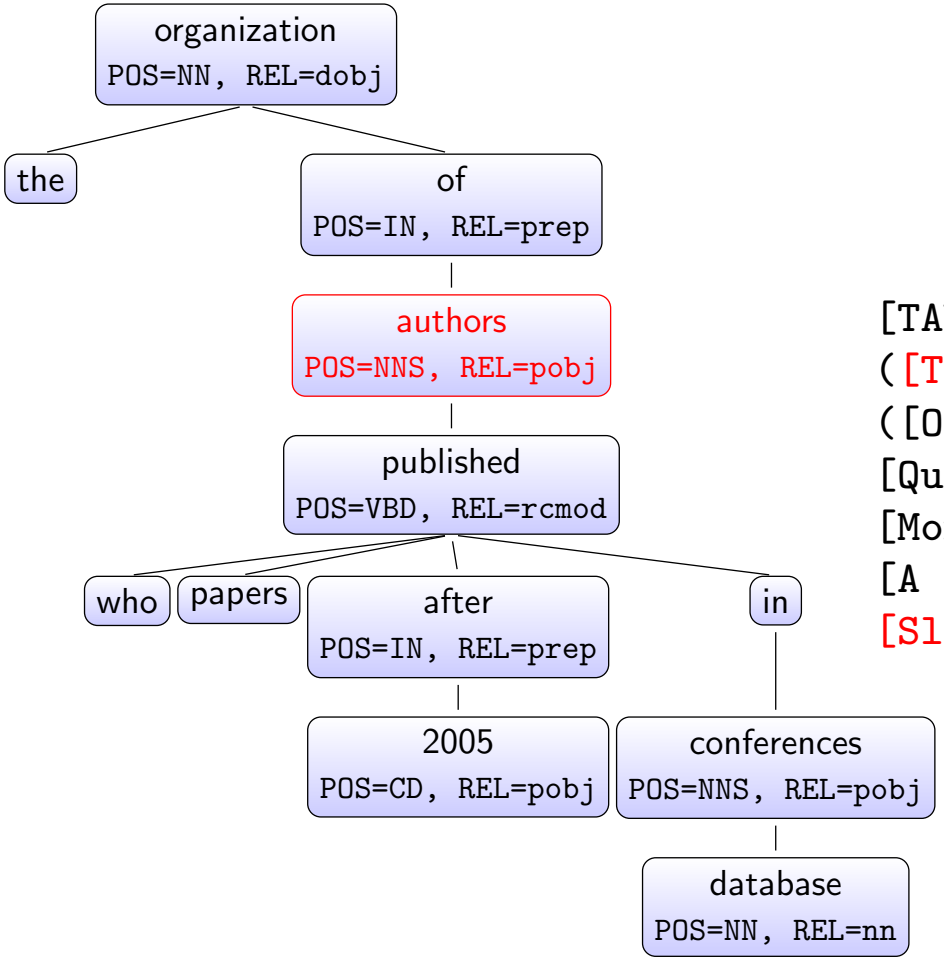

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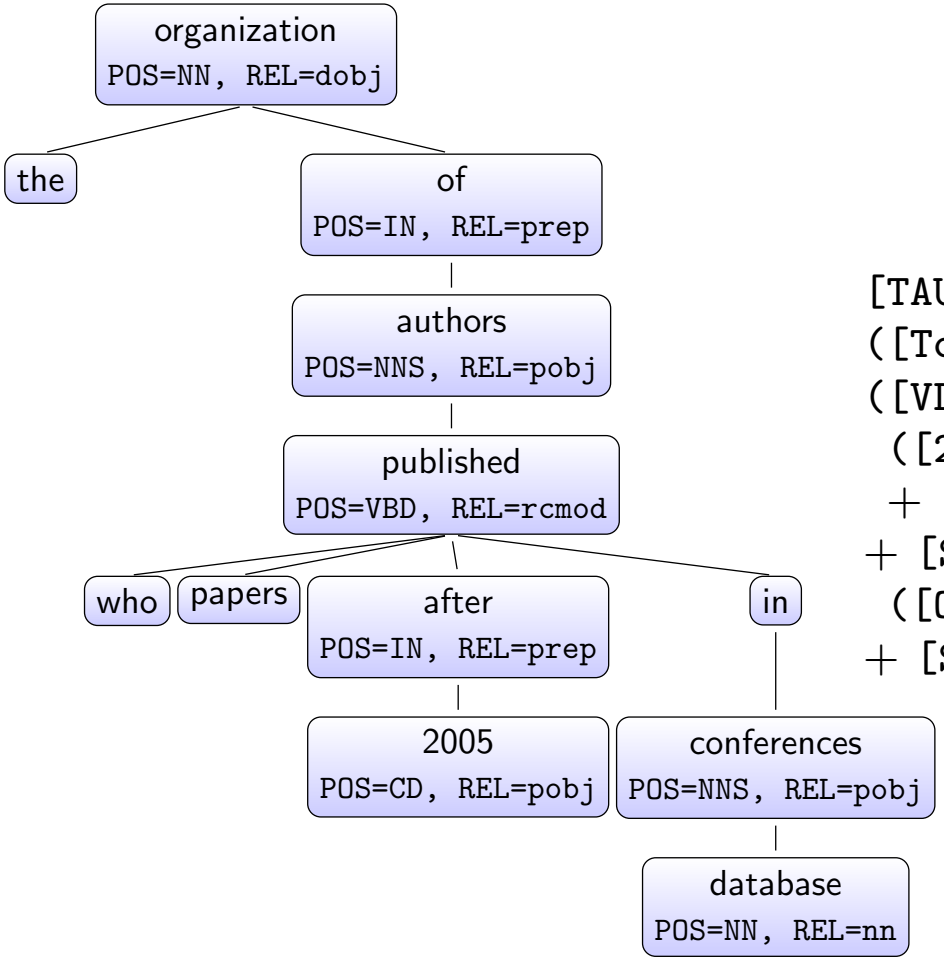


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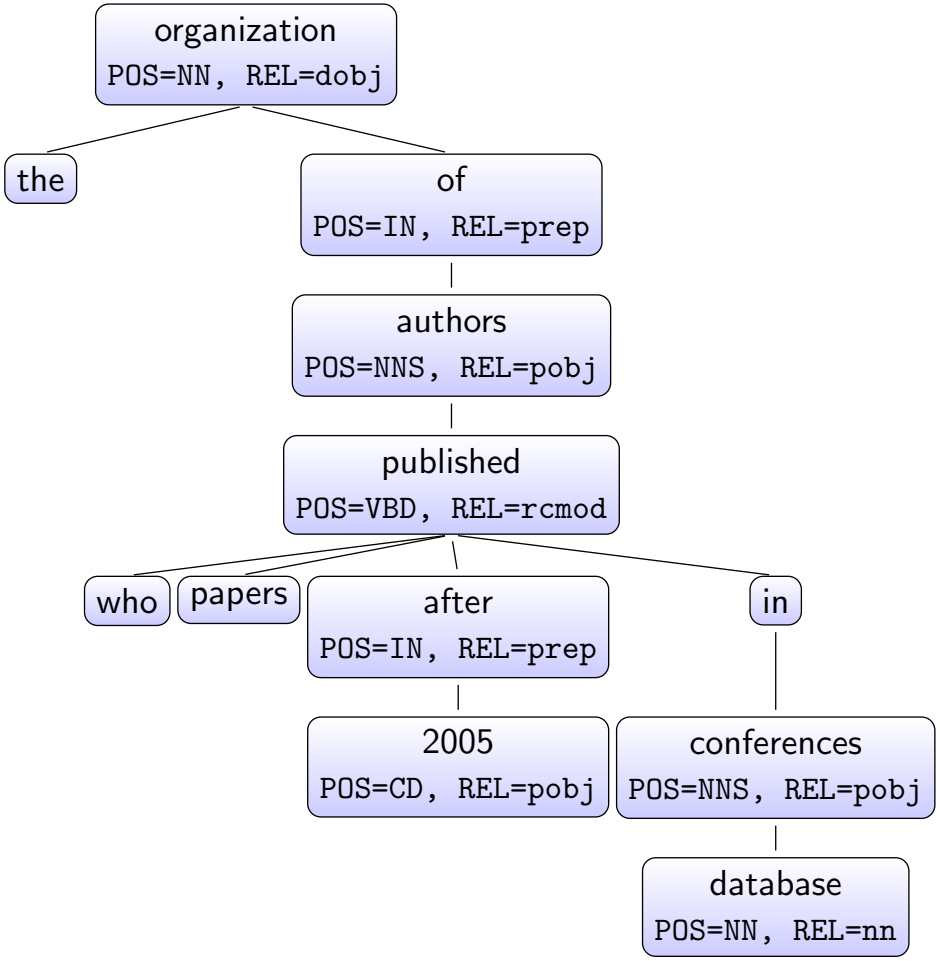


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```

Outline

Summarization

Two Levels of Summarization

```
[TAU] ·
  A { ([Tova M.] ·
        B { ([VLDB] ·
              ([2006] · [Querying...]
              + [2007] · [Monitoring...]))
            + [SIGMOD] · [2014] ·
              ([OASSIS...] + [A Sample...]))  } B
      + [Slava N.] · [OASSIS...] · [SIGMOD] · [2014]) } A
```

Shorter Summarized Answer Based on A

TAU is the organization of 2 authors who published 4 papers in 2 conferences in 2006 - 2014

More Detailed Summarized Answer Based on B

TAU is the organization of Tova M. who published 4 papers in 2 conferences in 2006 - 2014 and Slava N. who published 'OASSIS...' in SIGMOD in 2014.

Outline

Sample Use-Cases

Q: Return the authors who published papers in VLDB before 2016 and after 2007

- **A:** Tova M. published 16 papers in VLDB in 2008 - 2015

Q: Return the authors who published papers in database conferences

- **A:** Tova M. published 134 papers in 18 conferences

Q: Return the organization of authors who published papers in database conferences after 2005

- **A:** TAU is the organization of 43 authors who published 170 papers in 31 conferences in 2006 - 2015

Sample Use-Cases

Q: Return the authors who published papers in VLDB before 2016 and after 2007

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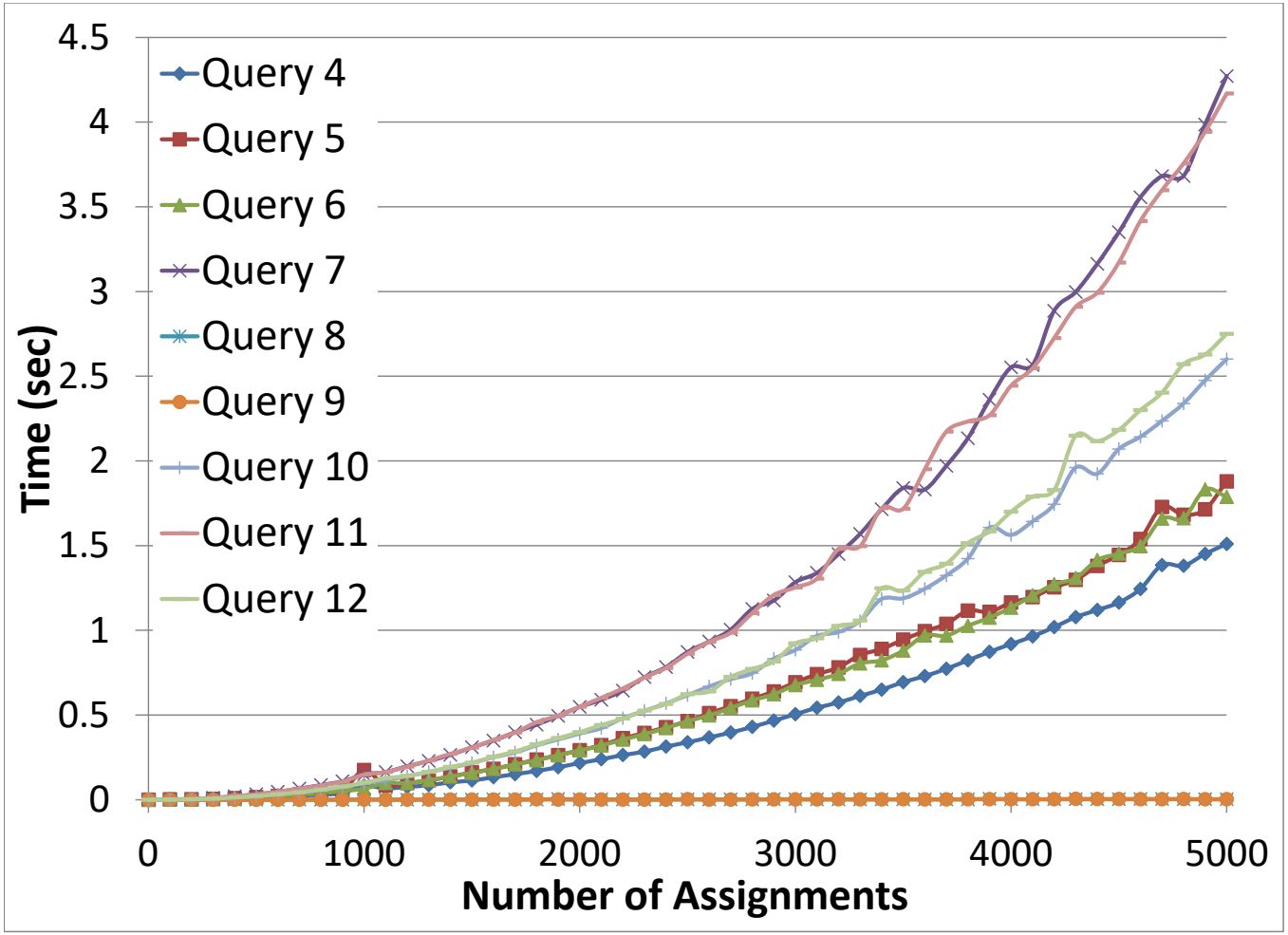
- **A:** Tova M. published 134 papers in 18 conferences

Q: Return the organization of authors who published papers in database conferences after 2005

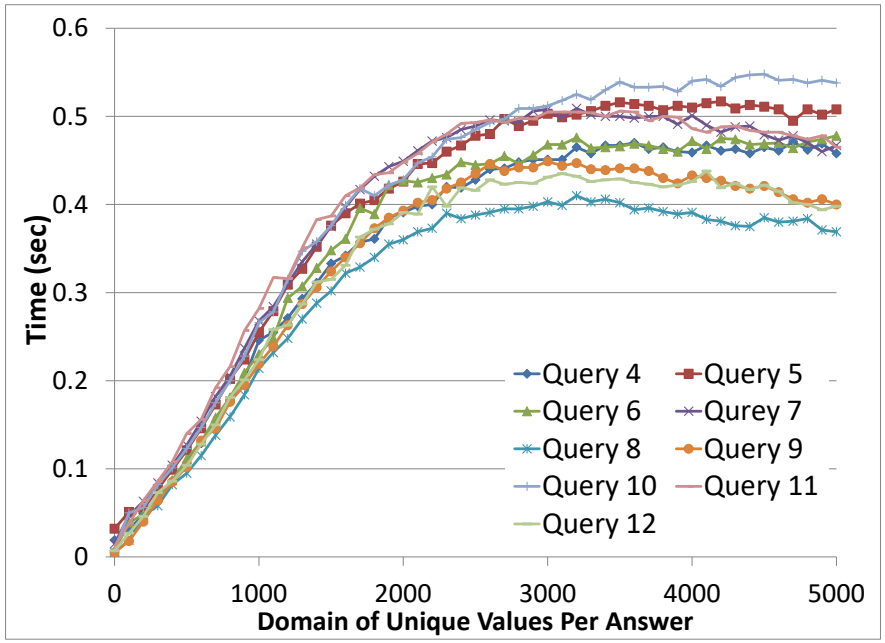
- **A:** TAU is the organization of 43 authors who published 170 papers in 31 conferences in 2006 - 2015

Sample Scalability Results

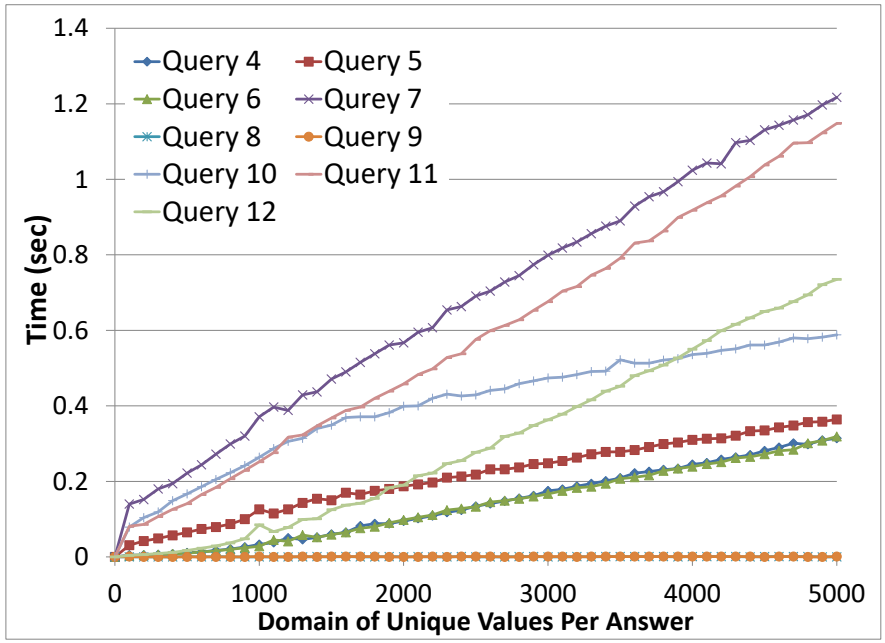
Computation time as a function of the number of assignments.
Overhead of only 16% w.r.t evaluation time.



Breakdown of Computation Time



(a) Factorization time



(b) Sentence gen. time

Summarization time was negligible.

Outline

Related Work

NL Interfaces:

- Formulate the NL query and present the answers, e.g., [Fei Li et al., 15'], [Song et al., 15']
- Present the answers in NL based on the schema [Franconi et al., 14']
- Explain the query in NL [Koutrika et al., 10']

Provenance:

- Showing the provenance in graph form, e.g., [Ailamaki et al., 98'], [Davidson et al., 08']
- Allowing user control over granularity [Cohen-Boulakia et al., 08']
- Provenance factorization and Summarization, e.g., [Chapman et al., 08'], [Olteanu et al., 12']

Summary

Main Contributions:

- First to formulate the *provenance* of output tuples in NL
- Employing both factorization and summarization to make provenance more understandable
- Devising a criterion for provenance factorization that accounts for its *presentation in NL*

Summary

Main Contributions:

- First to formulate the *provenance* of output tuples in NL
- Employing both factorization and summarization to make provenance more understandable
- Devising a criterion for provenance factorization that accounts for its *presentation in NL*

Future Work:

- Extend the solution to UCQs, aggregation, nested queries, ...
- Support more provenance models
- Generalize the requirements from NL interfaces

Thank You

Questions?