LinCQA: Faster Consistent Query Answering with Linear Time Guarantees

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SIGMOD, Seattle WA, June 18–23 2023

Primary key constraint (violated)

- Metadata of `stackoverflow.com` as of 02/2021 from Stack Exchange Data Dump
- 551M rows, ∼400 GB

Table	# of rows	inRatio	bSize	# of Attributes
Users	14M	0%	1	14
Posts	53M	0%	1	20
PostHistory	141M	0.001%	4	9
Badges	40M	0.58%	941	4
Votes	213M	30.9%	1441	6

inconsistencyRatio = # facts violating PK constraint / # of rows

blockSize = max. # facts with the same PK

Finding consistent answers

Course

c_id	f_id
CS 703	2
CS 703	5
CS 787	3
CS 787	5

CS_Faculty

f_id	f_name
2	Adam
2	Alice
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SELECT DISTINCT c_id
FROM Course, CS_Faculty
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$Q(\mathbf{db}) = \{\text{CS 703, CS 787}\}$ ...

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Data cleaning

$Q(\mathbf{rep})$

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Data cleaning $2 \times 2 \times 2 \times 1$ repairs

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Which answers are guaranteed to be returned on all repairs?

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Consistent Answer

Finding consistent answers without enumeration

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The original query Q has a first-order rewriting Q'

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For which Q can the consistent answers be found efficiently?

Can we build a system to find the consistent answers?

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Acyclic query evaluation

$$q() \text{ :- } \text{Course}(\underline{x}, y), \text{CS\_Faculty}(\underline{y}, z)$$

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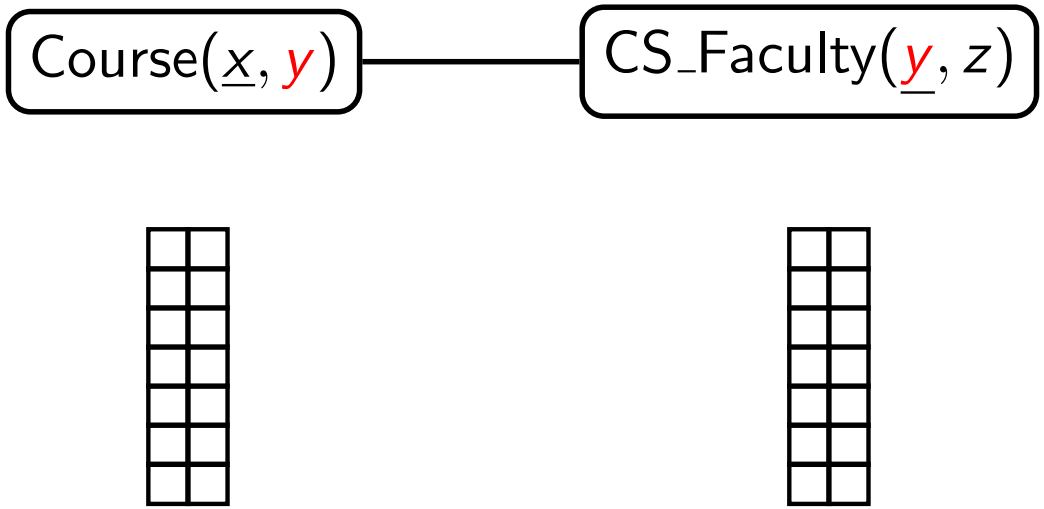

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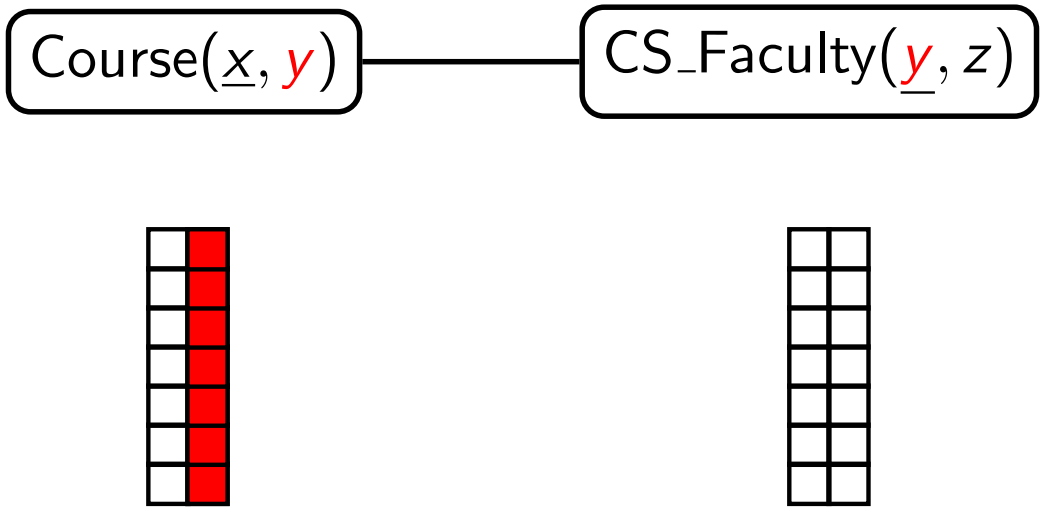

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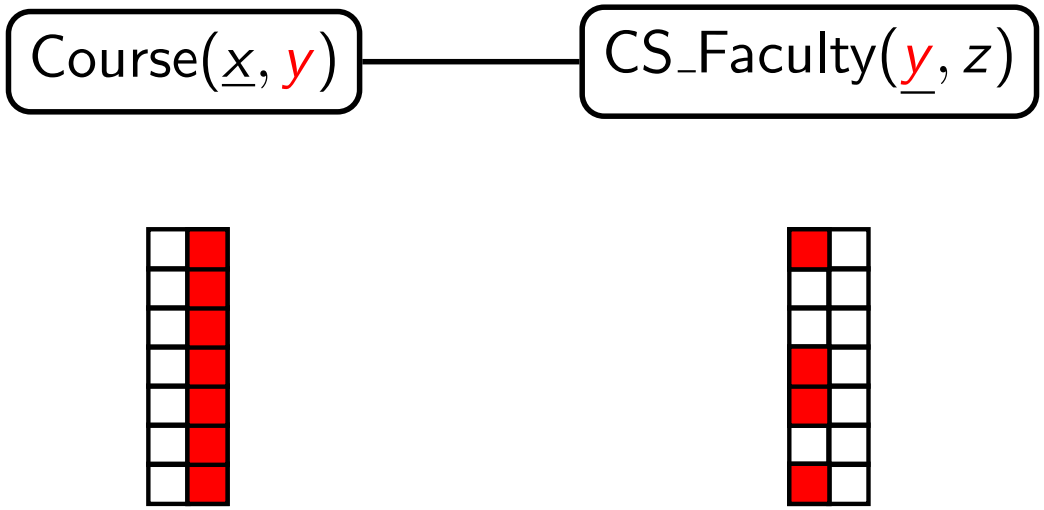

Yannakakis [VLDB'81]

The answer to every **Boolean** acyclic query can be computed in $O(|\mathbf{db}|)$.

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consistent answer

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with a pair-pruning join tree (PPJT)

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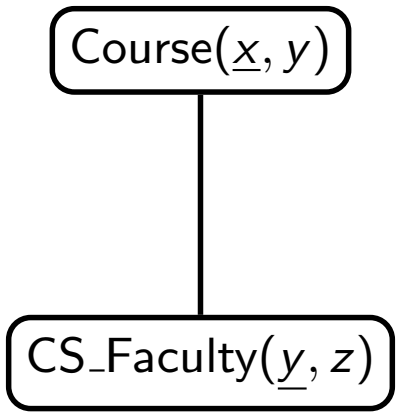
with a pair-pruning join tree (PPJT)

non-Boolean $\leq_T^P$ **Boolean**

Pair-pruning join tree (PPJT)

A join tree rooted at some atom is a PPJT if

the root of every subtree is unattacked in the subtree



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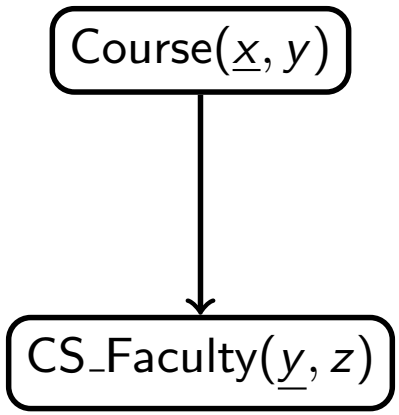

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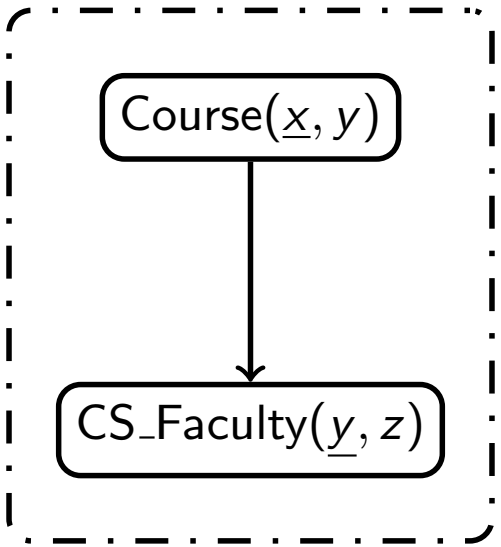

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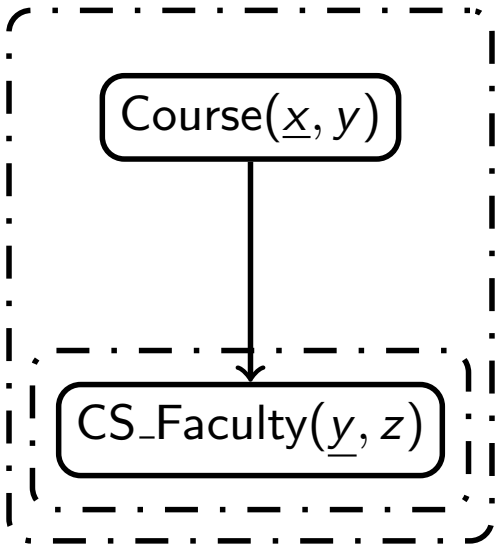

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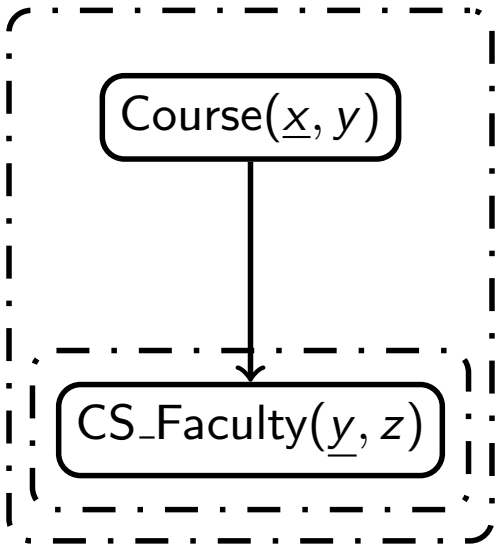

Every acyclic query has a join tree, but not every acyclic query has a PPJT

PPJT is a wide class

+ star/snowflake schema (e.g. TPC-H)
+ Every acyclic query in $\mathcal{C}_{\text{forest}}$ [FM, ICDT'05] has a PPJT

From PPJT to **FO**-rewriting

Remove a primary key if some tuple with this primary key is "bad"

$\text{Course}_{join}() \text{ :- } \text{Course}(x, y), \neg\text{Course}_{fkey}(x)$

$\text{Course}_{fkey}(x) \text{ :- } \text{Course}(x, y), \neg\text{Faculty}_{join}(y)$

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also expressible in SQL!
runs in $O(N)$

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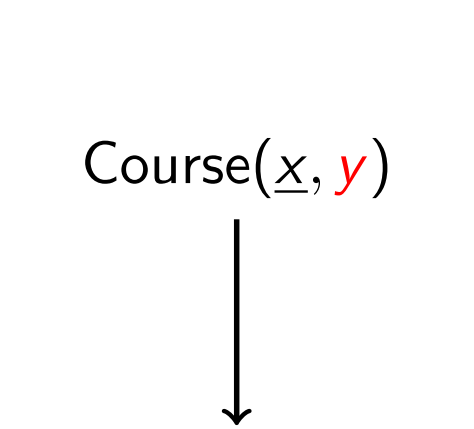

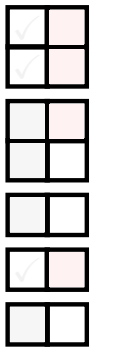

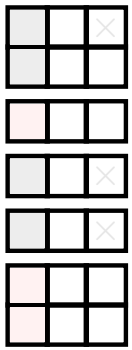

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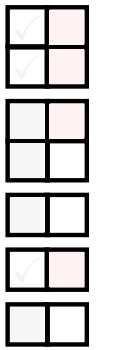

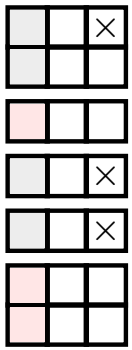

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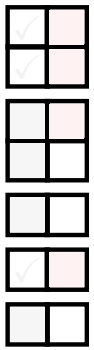

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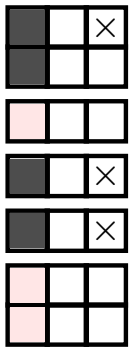

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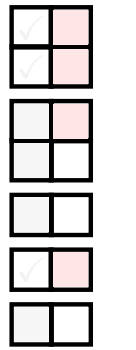

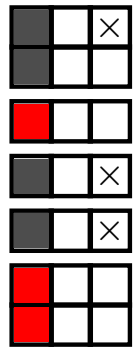

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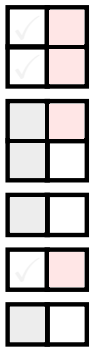

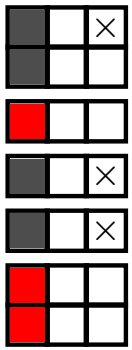

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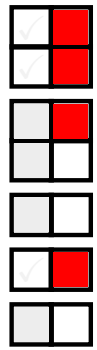

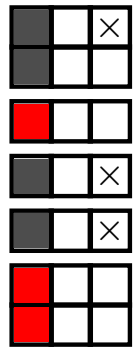

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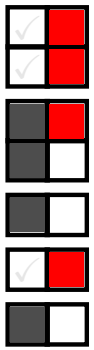
also expressible in SQL!

runs in $O(N)$

From PPJT to **FO**-rewriting

Remove a primary key if some tuple with this primary key is "bad"

$\text{Course}(\underline{x}, y)$



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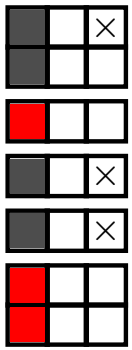

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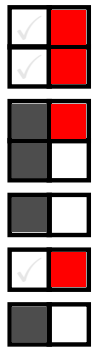

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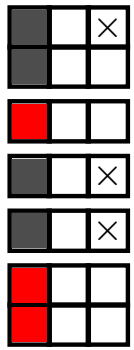

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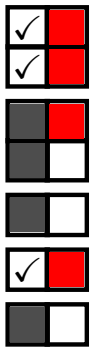

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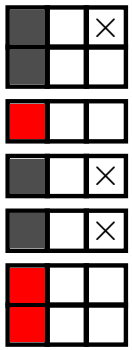

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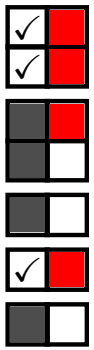

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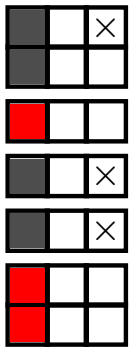

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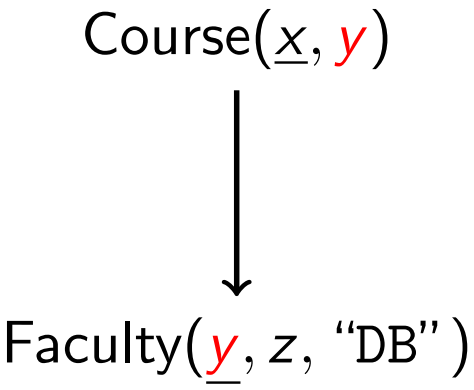

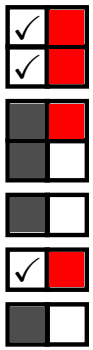

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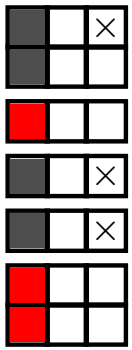

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From Boolean to non-Boolean

```
SELECT DISTINCT A1, A2 FROM T WHERE A3 = 42
```

Step 1 Evaluate directly

A1	A2
a	b
x	y
...	...

Step 2 Reduce to **Boolean** (using PPJT)

```
SELECT DISTINCT 1 FROM T WHERE A3 = 42 AND A1 = a AND A2 = b
```

if **yes**, then output (a, b), otherwise continue

```
SELECT DISTINCT 1 FROM T WHERE A3 = 42 AND A1 = x AND A2 = y
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...

$\xrightarrow{\text{LinCQA}}$ a single SQL/Datalog query

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Acyclic q	PPJT	Yannakakis [VLDB'81]
Boolean q	$O(N)$	$O(N)$
non-Boolean q	$O(N \cdot \lvert\mathsf{OUT}_{\mathsf{inconsistent}}\rvert)$	$O(N \cdot \lvert\mathsf{OUT}\rvert)$
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Setup & Baselines

System	Target class	Interm. output	Backend
CAvSAT	*	SAT formula	SQL Server & MaxHS
Conquer	$\mathcal{C}_{\text{forest}}$	SQL	SQL Server
Improved Conquesto	SJF **FO**	SQL	SQL Server
LinCQA	PPJT	SQL	SQL Server

Stackoverflow data

- Metadata of `stackoverflow.com` as of 02/2021 from Stack Exchange Data Dump
- 551M rows, 400 GB

Table	# of rows	inRatio	bSize	# of Attributes
Users	14M	0%	1	14
Posts	53M	0%	1	20
PostHistory	141M	0.001%	4	9
Badges	40M	0.58%	941	4
Votes	213M	30.9%	1441	6

Experiments on Stackoverflow

Q_1 : Posts $\bowtie$ Votes Q_2 : Users $\bowtie$ Badges Q_3 : Users $\bowtie$ Posts

Q_4 : Users $\bowtie$ Posts $\bowtie$ Comments

Q_5 : Posts $\bowtie$ PostHistory $\bowtie$ Votes $\bowtie$ Comments

```
SELECT DISTINCT Posts.Title
FROM Posts, PostHistory, Votes, Comments
WHERE Posts.Tags LIKE "%SQL%"
    AND Posts.id = PostHistory.PostId
    AND Posts.id = Comments.PostId
    AND Posts.id = Votes.PostId
    AND Votes.BountyAmount > 100
    AND PostHistory.PostHistoryTypeId = 2
    AND Comments.score = 0
```

Experiments on Stackoverflow

Q_1 : Posts $\bowtie$ Votes Q_2 : Users $\bowtie$ Badges Q_3 : Users $\bowtie$ Posts

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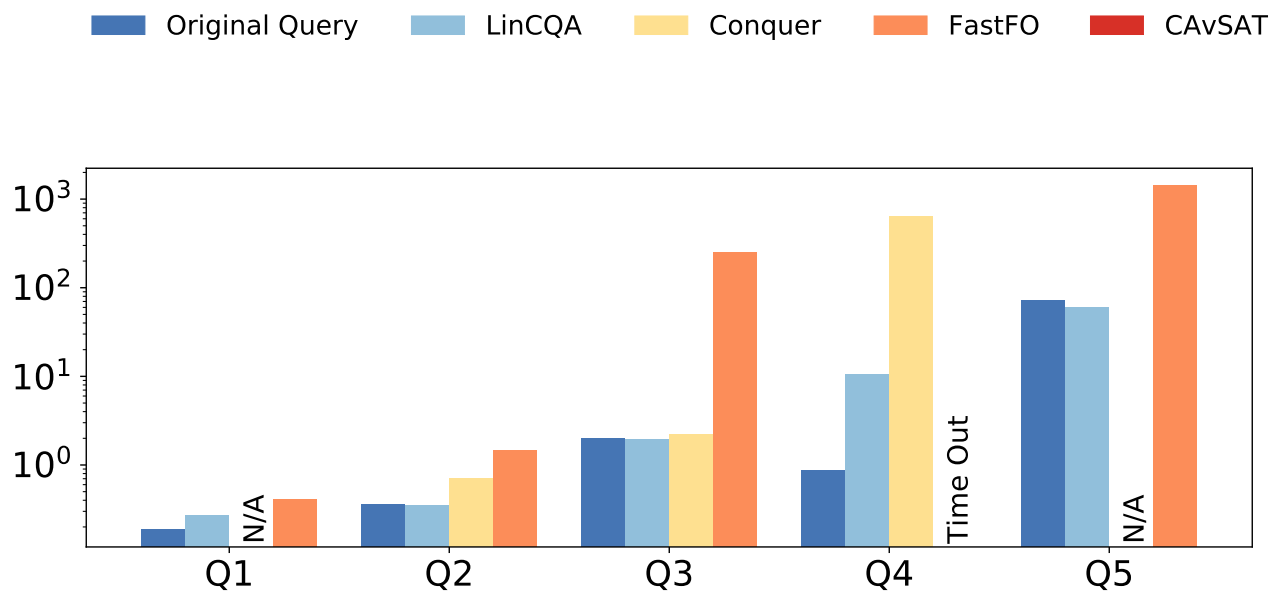

# poss.	27578	145	38320	3925	1250
# cons.	27578	145	38320	3925	1245

Concluding remarks

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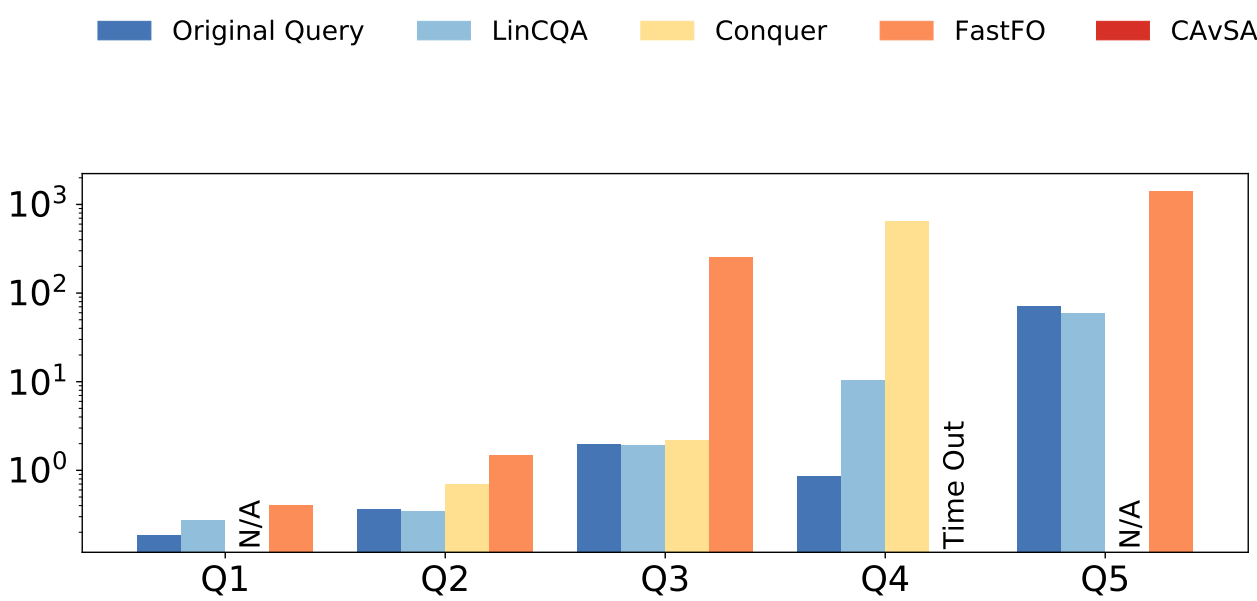

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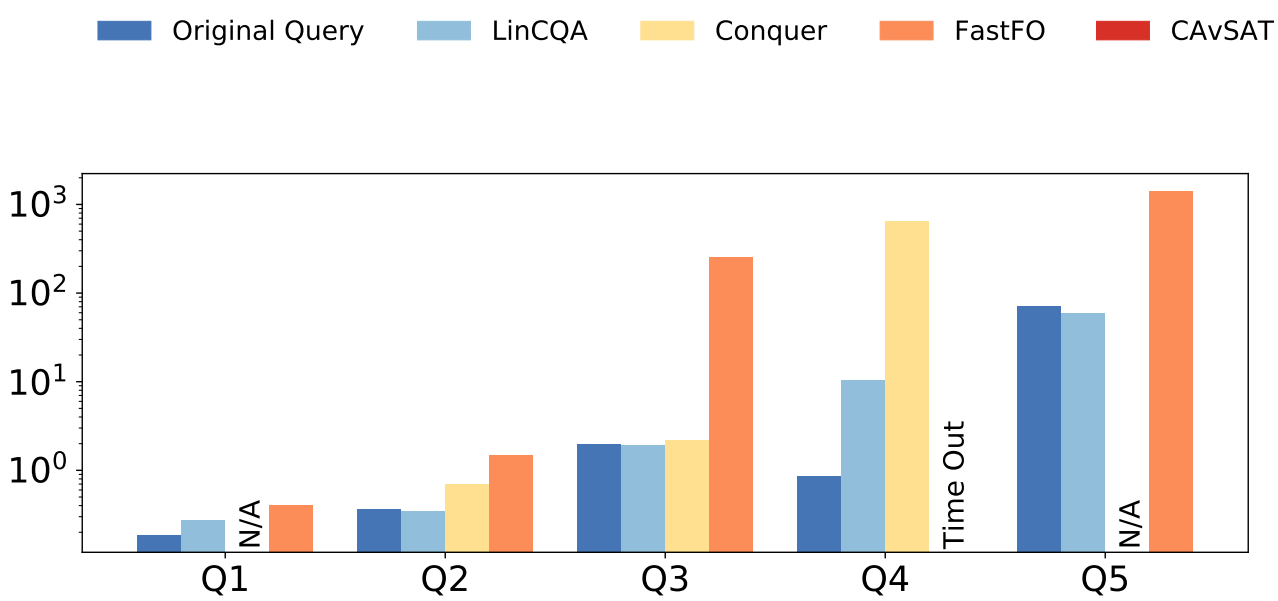

Thank you!