Contrasting RDF Stream Processing Semantics

Minh Dao-Tran Harald Beck Thomas Eiter

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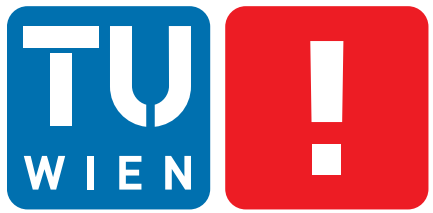

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Outline

Illustrating Scenario

Divergence in RDF Stream Processing (RSP)

A **L**ogic for **A**nalyzing **R**easoning over **S**treams (LARS [Beck *et al.*, 2015])

Capturing and Comparing C-SPARQL and CQELS with LARS

Illustrating Scenario

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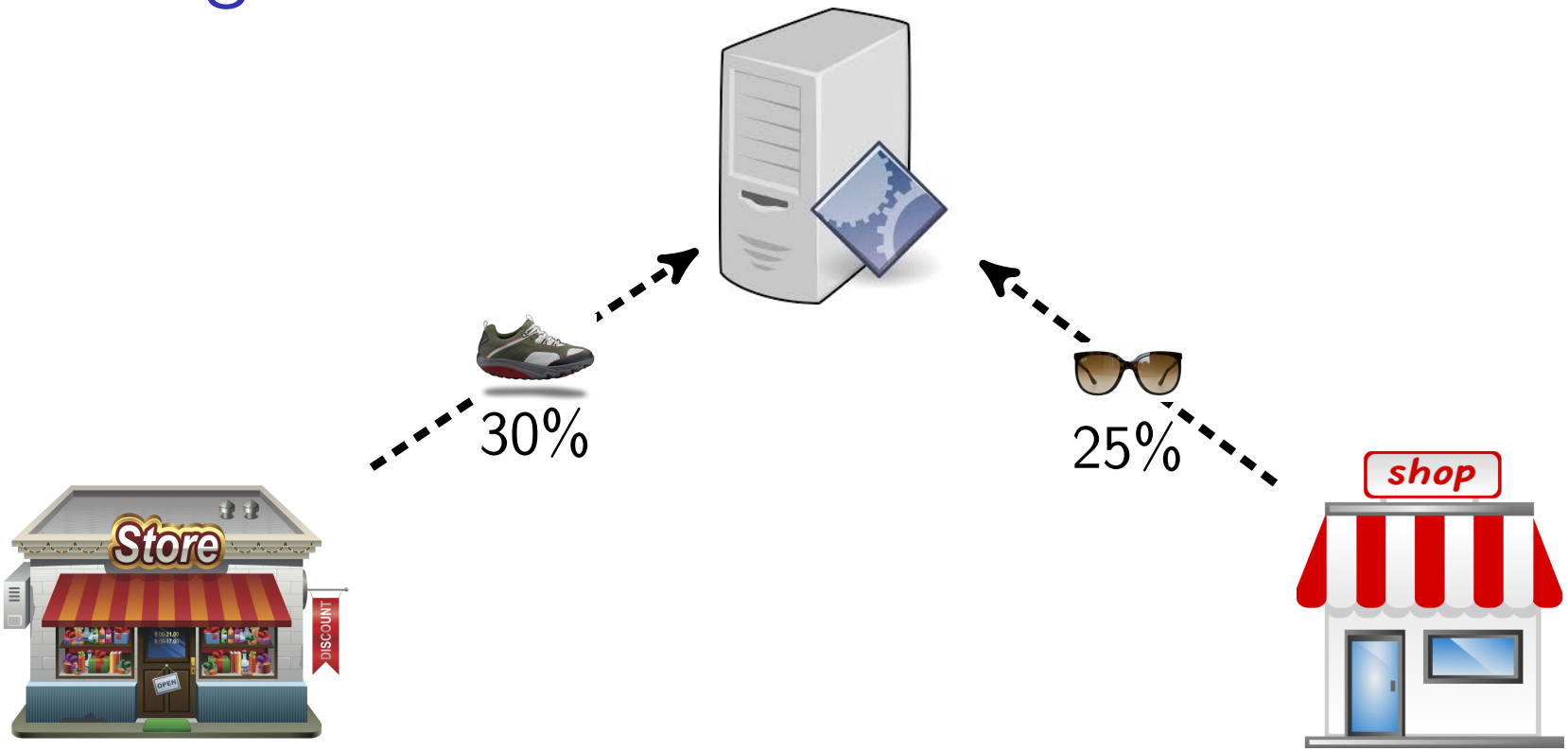

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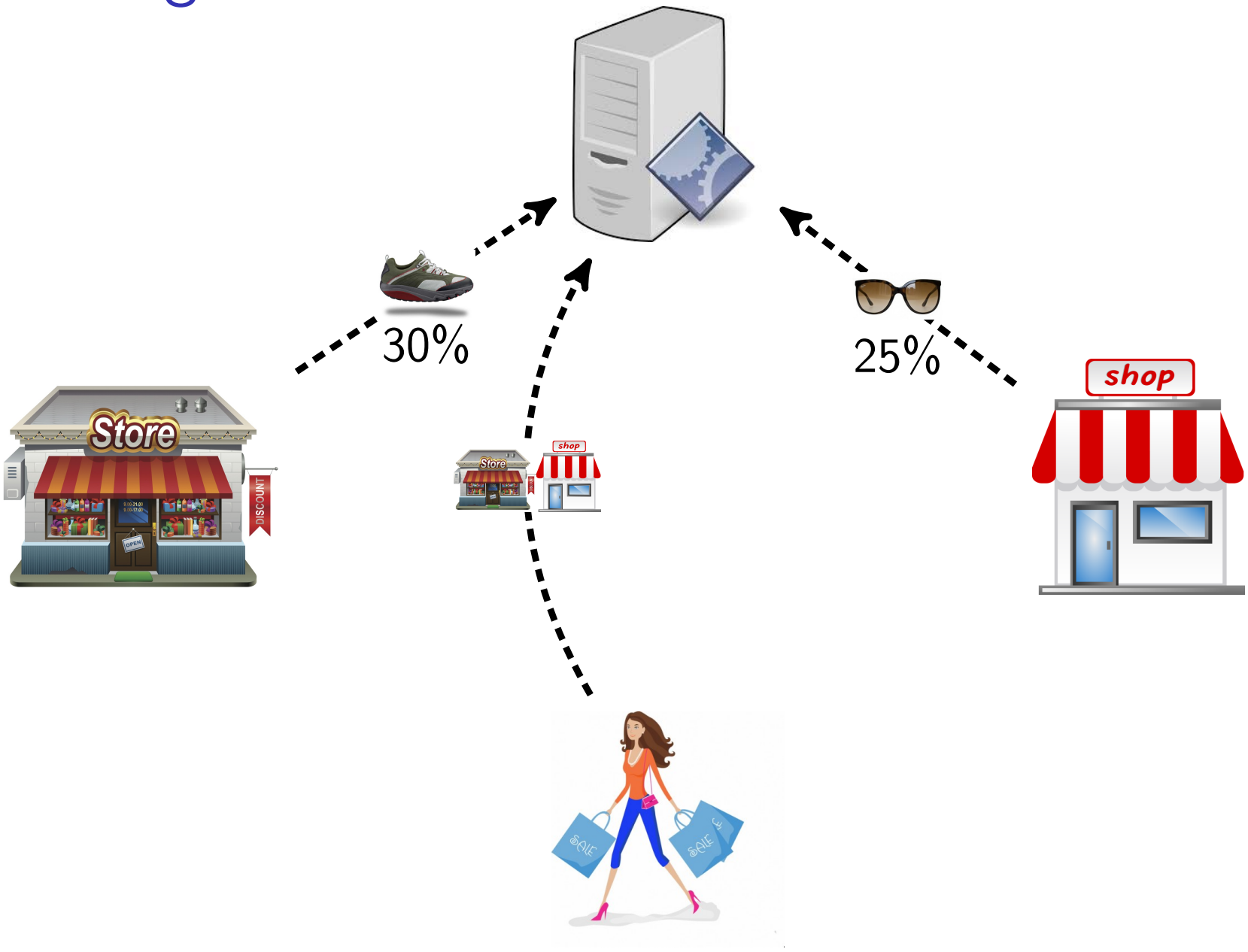

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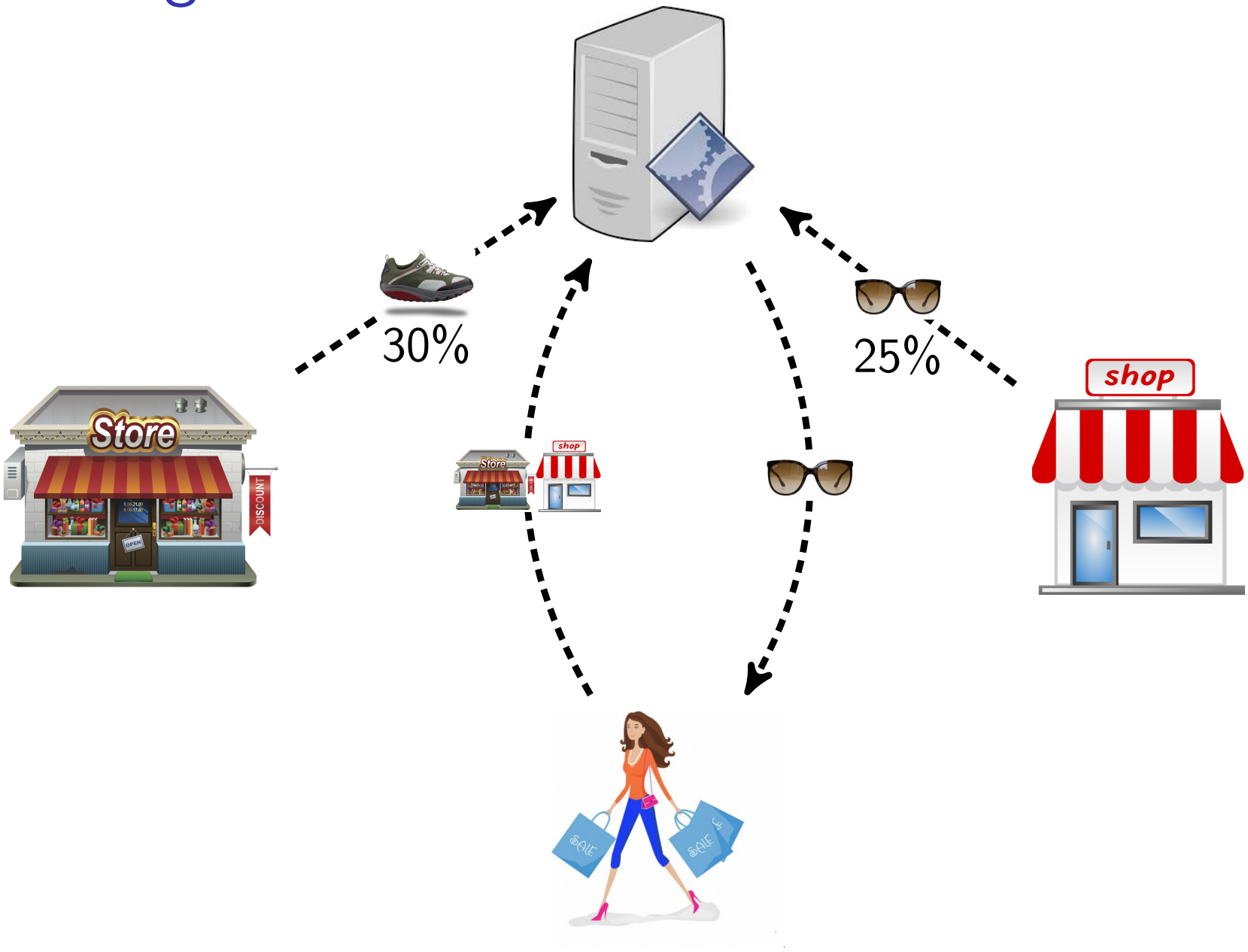

RDF Stream Processing at a Glance

Extend RDF data model with the temporal aspect

- RDF streams = RDF triples/graphs + timestamps

Extend SPARQL with window operators

- Adapt CQL [Arasu *et al.*, 2006] to SPARQL

Recent Developments in RSP

RSP Query Engines:

- C-SPARQL [Barbieri *et al.*, 2010]
- CQELS [Phuoc *et al.*, 2011]
- SPARQL_{Stream} [Calbimonte *et al.*, 2010]
- ...

Benchmarking systems:

- LSBench [Phuoc *et al.*, 2012]
- SRBench [Zhang *et al.*, 2012]
- CSRBench [Dell'Aglio *et al.*, 2013]
- YABench [Kolchin and Wetz, 2015]

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All comparison at the operational level!

RSP Divergence

```
SELECT ?shop ?product ?percent
  FROM <products>
  STREAM <coupons>   [RANGE 30m]
  STREAM <locations> [RANGE 5m]
WHERE {
  ?shop    :offers     ?coupon.  ?coupon :reduce ?percent.
  ?coupon  :on         ?product. ?user   :isNear ?shop.
  ?product :g_classify ?gender.
  FILTER
  (?percent >= 20 && ?gender != 1)}
```

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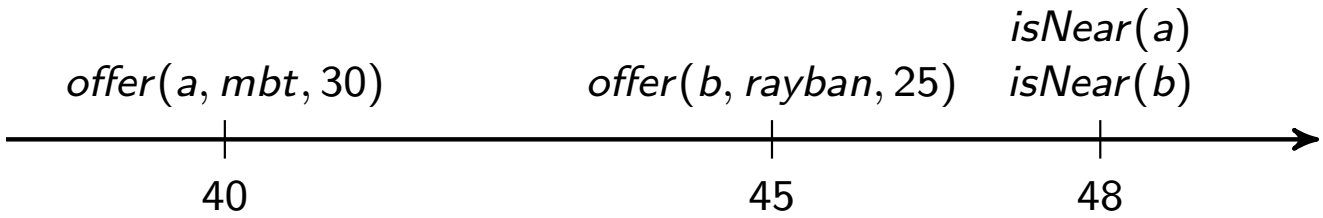
```

Key Differences between C-SPARQL and CQELS

	C-SPARQL	CQELS
create snapshot	merge patterns on input streams into the default graph	apply patterns on input streams
execution mode	pull-based	push-based

LARS in a Nutshell: Stream Representation

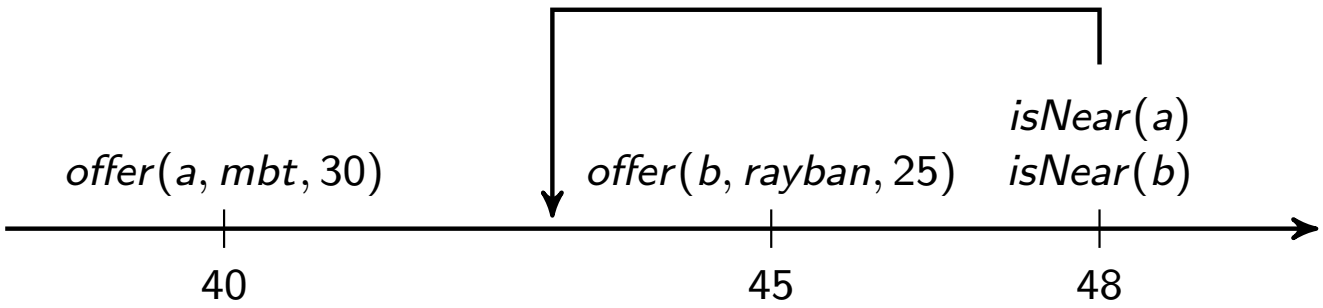
$S = (T, \upsilon)$



$T = [0, 50]$

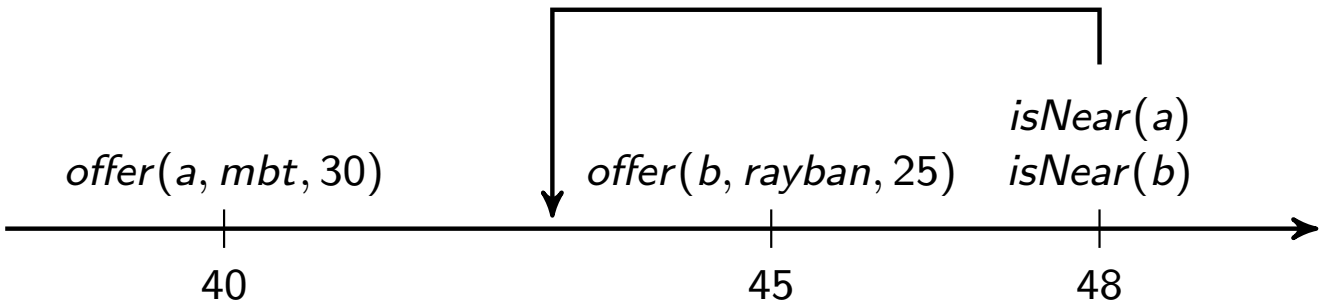
$$\upsilon = \left\{ \begin{array}{l} 40 \mapsto \{offer(a, mbt, 30)\}, 45 \mapsto \{offer(b, rayban, 25)\} \\ 48 \mapsto \{isNear(a), isNear(b)\} \end{array} \right\}$$

LARS in a Nutshell: Window functions



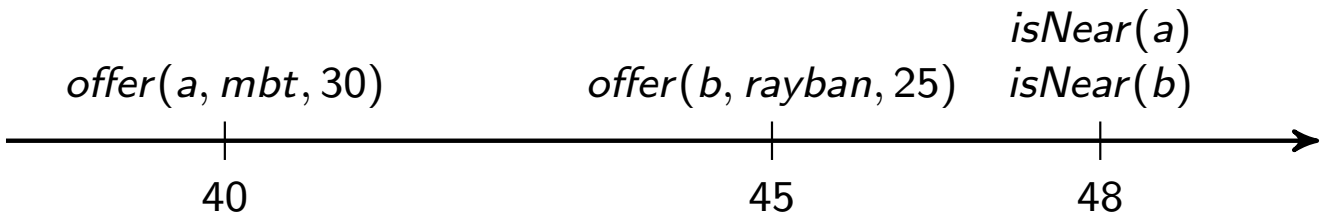
$$S' = w_\iota(S, t, \vec{x})$$

LARS in a Nutshell: Window functions



$$S' = w(S, 48, (5, 0, 1)) = ([43, 48], \left\{ \begin{array}{l} 45 \mapsto \{offer(b, rayban, 25)\} \\ 48 \mapsto \{isNear(a), isNear(b)\} \end{array} \right\})$$

LARS in a Nutshell: LARS formulas



$\alpha ::=$

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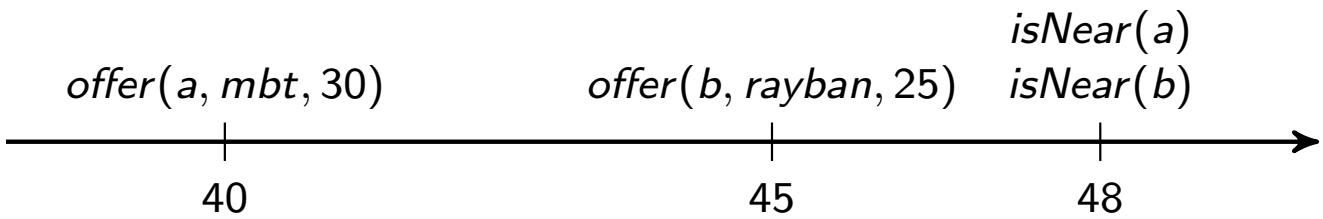
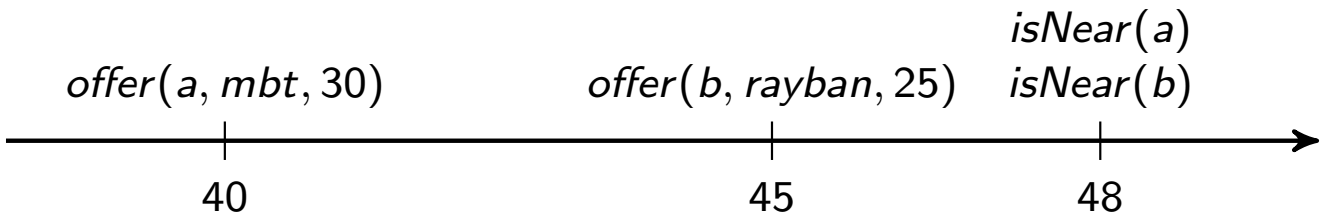


$$\alpha ::= a \mid \neg\alpha \mid \alpha \wedge \alpha \mid \alpha \vee \alpha \mid \alpha \rightarrow \alpha$$

LARS in a Nutshell: LARS formulas



$$\alpha ::= a \mid \neg\alpha \mid \alpha \wedge \alpha \mid \alpha \vee \alpha \mid \alpha \rightarrow \alpha \mid \Diamond\alpha \mid \Box\alpha \mid @_t\alpha$$

- various ways for time references

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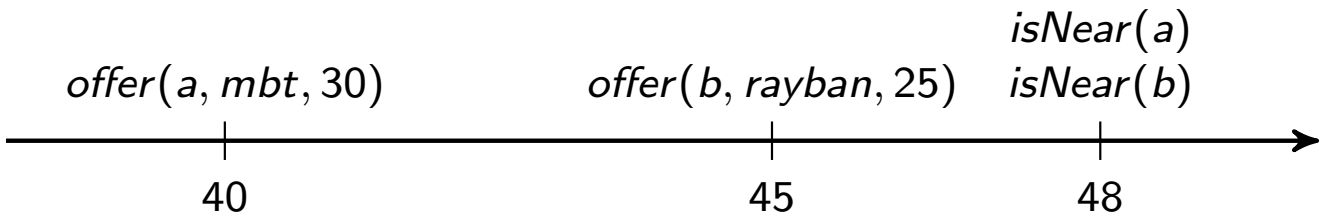

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- various ways for time references
- window operators with possibility to nest

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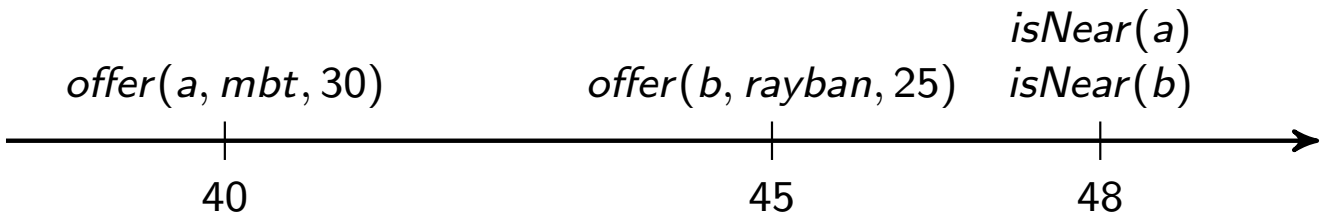

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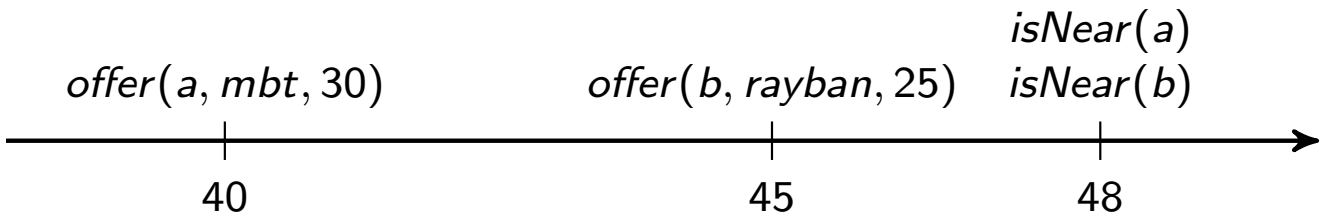

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- various ways for time references
- window operators with possibility to nest
- $\boxplus^{10}\Diamond offer(Sh, Pr, Pe)$
- $\boxplus^{5}\Box isNear(a)$

LARS in a Nutshell: LARS rules/programs

$$\alpha \leftarrow \beta_1, \ldots, \beta_j, \text{not } \beta_{j+1}, \ldots, \text{not } \beta_n.$$

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$$\alpha \leftarrow \beta_1, \ldots, \beta_j, \text{not } \beta_{j+1}, \ldots, \text{not } \beta_n.$$

$$\begin{aligned} ans(Sh, Pr, Pe) \leftarrow\ & \boxplus^{30} \Diamond offer(Sh, Pr, Pe), \boxplus^{5} \Diamond isNear(Sh), \\ & g\_classify(Pr, Ge), Pe \geq 20, Ge \neq 1. \end{aligned}$$

LARS in a Nutshell: Semantics

- extend Answer Set Programming semantics
- answer streams: input stream + intentional facts + satisfaction + minimality

LARS to Analyze RSP Queries

Translations from RSP queries to LARS programs:

- offer the correspondence between query answers and answer streams
- capture differences in RSP queries:
  - creating snapshots
  - execution modes

LARS to Analyze RSP Queries (cont'd)

Comparison based on LARS:

- Difference in creating snapshots: can be remedied in practice
- Difference in execution modes: agreement can only be possible interval-wise, on non-dense input streams.

Conclusions

Identify crucial divergences in RSP engines' semantics

Introduce a common model for RSP queries (details in paper)

Capture and analyze the difference of C-SPARQL and CQELS with LARS

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