

Towards Comparing RDF Stream Processing Semantics

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Stream Processing**

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RDF STREAM PROCESSING COMMUNITY GROUP

The mission of the RDF Stream Processing Community Group (RSP) is to define a common model for producing, transmitting and continuously querying RDF Streams. This includes extensions to both RDF and SPARQL for representing streaming data, as well as their semantics. Moreover this work envisions an ecosystem of streaming and static RDF data sources whose data can be combined through standard models, languages and protocols. Complementary to related work in the area of databases, this Community Group looks at the dynamic properties of graph-based data, i.e., graphs that are produced over time and which may change their shape and data over time.

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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- ▶ YABench [Kolchin and Wetz, 2015]

All comparison at the operational level!

Comparison at the Semantics Level?



Outline

Running scenario

RDF & RDF Stream Processing (RSP)

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

Capturing RSP with LARS

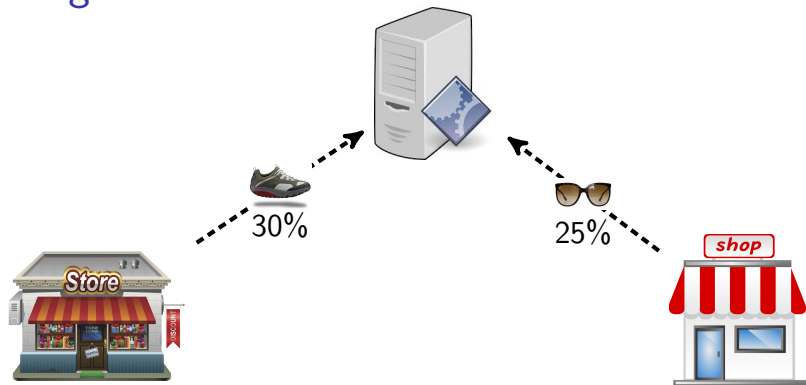
Running Scenario



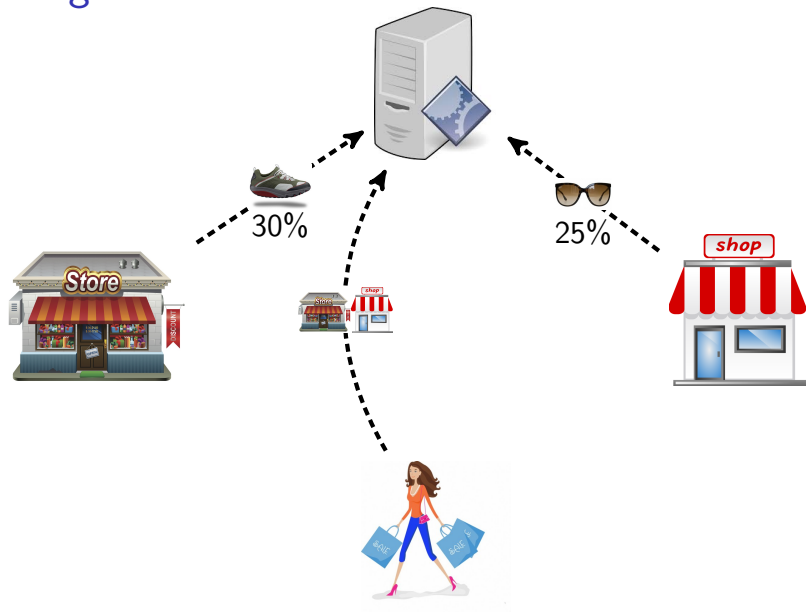
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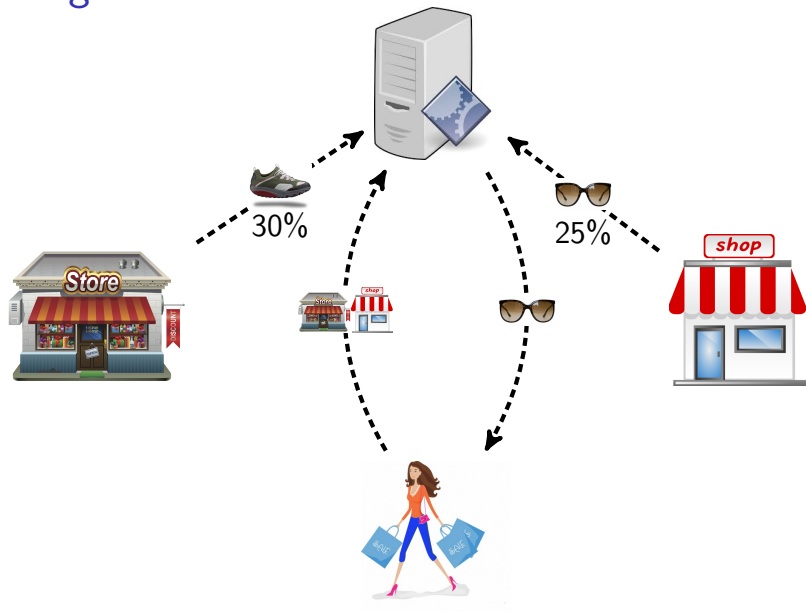
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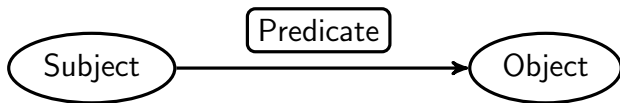


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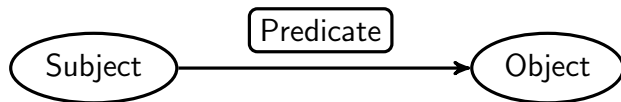


RDF

RDF



RDF



$G = \{ \text{"mbt"} :g_classify :1. \text{"rayban"} :g_classify :0. \dots \}$

$g_1 = \{ :a :offers :c_1. :c_1 :on : \text{"mbt"}. :c_1 :reduce :30. \}$

$g_2 = \{ :b :offers :c_2. :c_2 :on : \text{"rayban"}. :c_2 :reduce :25. \}$

$g_3 = \{ : \text{"claire"} :isNear :a. : \text{"claire"} :isNear :b. \}$

SPARQL

SELECT

FROM

WHERE

SPARQL

```
SELECT ?shop ?product ?percent
```

```
FROM
```

```
WHERE
```


SPARQL

```
SELECT ?shop ?product ?percent
FROM   <http://products>
       <http://coupons_snapshot>
       <http://locations_snapshot>
WHERE
```

SPARQL

```
SELECT ?shop ?product ?percent
FROM   <http://products>
       <http://coupons_snapshot>
       <http://locations_snapshot>
WHERE  {?shop      :offers      ?coupon.
        ?coupon    :reduce      ?percent.
        ?coupon    :on          ?product.
        ?user      :isNear      ?shop.
        ?product   :g_classify  ?gender.}
```

SPARQL

```
SELECT ?shop ?product ?percent
FROM   <http://products>
       <http://coupons_snapshot>
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WHERE  {?shop      :offers      ?coupon.
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        ?coupon    :on          ?product.
        ?user      :isNear      ?shop.
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        FILTER (?percent >= 20 && ?gender != 1)}
```

SPARQL

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        ?coupon    :on          ?product.
        ?user      :isNear      ?shop.
        ?product   :g_classify  ?gender.
FILTER (?percent >= 20 && ?gender != 1)}
μ = {?shop ↦ a, ?product ↦ "rayban", ?percent ↦ 25}
```

RDF Stream Processing Queries in C-SPARQL

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

RDF Stream Processing Queries in CQELS

```
SELECT ?shop ?product ?percent
FROM   <http://products>

WHERE {
  <http://coupons_stream> [RANGE 30m] {
    ?shop      :offers      ?coupon.
    ?coupon    :reduce      ?percent.
    ?coupon    :on          ?product.}
  <http://locations_stream> [RANGE 5m] {
    ?user      :isNear      ?shop.}
    ?product  :g_classify   ?gender.
}

FILTER (?percent >= 20 && ?gender != 1)}
```

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

Modeling RSP Queries $Q = (V, P, \mathcal{D}, \mathcal{S})$

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$V = \{?shop, ?pname, ?percent\}$

$P = (P_1 \cup P_2 \cup P_3) \text{ FILTER } R$

$P_1 = \left\{ \begin{array}{l} ?shop \quad :offers \quad ?coupon. \\ ?coupon \quad :on \quad ?product. \\ ?coupon \quad :reduce \quad ?percent. \end{array} \right\}$

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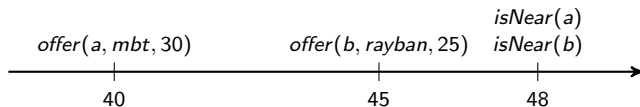
$R = (?percent \geq 20 \ \&\& \ ?gender \neq 1)$

$\mathcal{D} = \{<products>\}$

$\mathcal{S} = \left\{ \begin{array}{l} (<http://coupons>, [RANGE 30m], P_1), \\ (<http://locations>, [RANGE 5m], P_2) \end{array} \right\}.$

LARS in a Nutshell: Stream Representation

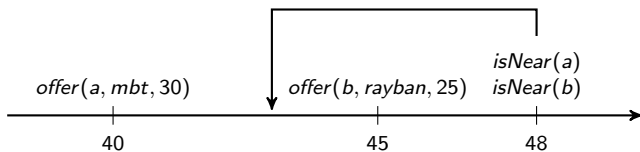
$$S = (T, v)$$



$$T = [0, 50]$$

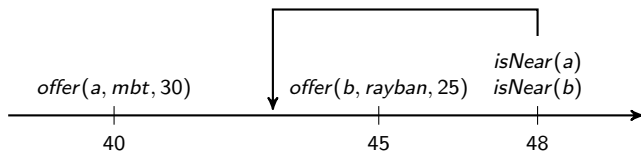
$$v = \left\{ \begin{array}{l} 40 \mapsto \{ \textit{offer}(a, \textit{mbt}, 30) \}, 45 \mapsto \{ \textit{offer}(b, \textit{rayban}, 25) \} \\ 48 \mapsto \{ \textit{isNear}(a), \textit{isNear}(b) \} \end{array} \right\}$$

LARS in a Nutshell: Window functions



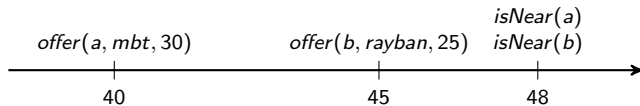
$$S' = w_t(S, t, \vec{x})$$

LARS in a Nutshell: Window functions



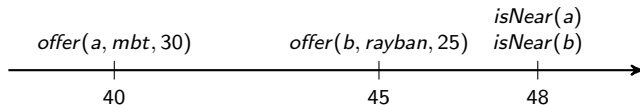
$$S' = w(S, 48, (5, 0, 1)) = ([43, 48], \left\{ \begin{array}{l} 45 \mapsto \{offer(b, rayban, 25)\} \\ 48 \mapsto \{isNear(a), isNear(b)\} \end{array} \right\})$$

LARS in a Nutshell: LARS formulas



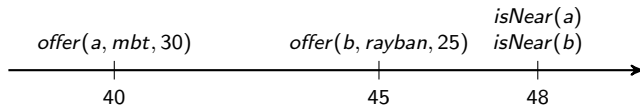
$\alpha ::=$

LARS in a Nutshell: LARS formulas



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

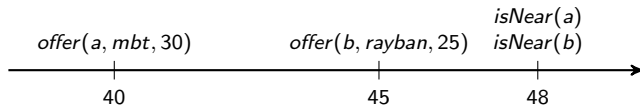
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- ▶ various ways for time references

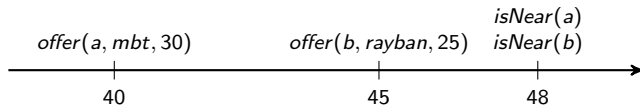
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- ▶ various ways for time references
- ▶ window operators with possibility to nest

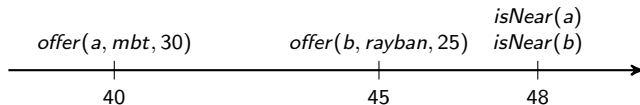
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- ▶ $\boxplus^{10}\diamond offer(Sh, Pr, Pe)$

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

LARS in a Nutshell: LARS rules/programs

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

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LARS in a Nutshell: Semantics

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

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$I = ([0, 50], v_I)$ where

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

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:
 - ▶ execution modes
 - ▶ creating snapshots

Translations at a Glance

Capture push-, pull-based execution modes:

$$\text{trigger}(r) = H(r) \leftarrow B(r), \text{trig.}$$

$$\text{trigger}(P) = \{\text{trigger}(r) \mid r \in P \wedge B(r) \neq \emptyset\}$$

$$\triangleright(P) = \text{trigger}(P) \cup \{\text{trig} \leftarrow \boxplus_{\text{NOW}} p(\vec{X}). \mid p \in \mathcal{A}^I\}$$

$$\triangleleft(P, U) = \text{trigger}(P) \cup \{\text{trig} \leftarrow \boxplus_{\text{NOW}} @_T \text{true}, T \% U = 0.\}$$

Translations at a Glance

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Capture SPARQL operators: extend a translation from SPARQL to Datalog [Polleres, 2007]

Conclusions and Future Work

- ▶ A unified query model for RSP
- ▶ Translations from RSP queries to LARS programs
- ▶ Next:
 - ▶ Comparing RSP semantics by comparing translated LARS programs
 - ▶ Equivalence of LARS programs

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