Stream Reasoning for Urban Computing

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Background

- **Data streams** are unbounded sequences of time-varying data elements;

- They occur in a variety of modern applications, such as network monitoring, traffic engineering, sensor networks, RFID tags applications, telecom call records, financial applications, Web logs, click-streams, etc.

- While **reasoners are** year after year **scaling up** in the classical, time invariant domain of ontological knowledge, reasoning upon rapidly changing information has been neglected or forgotten.

- On the contrary, processing of **data streams has been largely investigated** and specialized Stream Database Management Systems exist.
Existing technology: stream databases

Background: stream database key concepts

- Streams: continuous instead of one-time semantics
- Selecting by sliding Windows on streams
- Selecting by sampling on streams

Query Execution

- When a continuous query is registered, generate a query execution plan
- New plan merged with existing plans
- Plans composed of three main components:
  - Operators
  - Queues (input and inter-operator)
  - State (windows, operators requiring history)
- Global scheduler for plan execution maximizing experience gathered with previous queries.
Stream DB + semantics = Stream Reasoning

- **RDF streams**: new data formats set at the confluence of conventional data streams and of conventional atoms usually injected into reasoners.

- **Continuous SPARQL (C-SPARQL)**
  The distinguishing feature of C-SPARQL is the support for continuous queries, i.e. SPARQL-like queries registered over RDF data streams in the context of a C-SPARQL execution environment and then continuously executed.

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**Problem Modeling Framework**

- **Data Streams**
  - Stream data schema
  - Sampling and filtering policy

- **Select**
  - Sampled Streams

- **Abstract**
  - RDF Streams

- **Reason**
  - Answers

- **Decide**
  - Answer quality metrics
  - Decision Criteria

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**Streams**

- **Streamed Input**
- **Sampled Streams**
- **RDF Streams**
- **Answers**

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**Data stream element**  **RDF stream element**  **configuration action**  **tuning action**
The combination of reasoning techniques with data streams gives rise to **Stream Reasoning**, an unexplored, yet high impact, research area.

To understand the potential impact of Stream Reasoning, we can consider the emblematic case of **Urban Computing** (i.e., the application of pervasive computing to urban environments).
Cities are alive

- Cities born, grow, evolve like living beings.
- The state of a city changes continuously, influenced by a lot of factors,
  - human ones: people moving in the city or extending it
  - natural ones: precipitations or climate changes

[source http://www.citysense.com]
Today Cities’ Challenges

- Our cities face many challenges

- How can we redevelop existing neighbourhoods and business districts to improve the quality of life?
- How can we create more choices in housing, accommodating diverse lifestyles and all income levels?
- How can we reduce traffic congestion yet stay connected?
- How can we include citizens in planning their communities rather than limiting input to only those affected by the next project?
- How can we fund schools, bridges, roads, and clean water while meeting short-term costs of increased security?

[ source http://www.uli.org/ ]
Urban Computing

[source IEEE Pervasive Computing, July-September 2007 (Vol. 6, No. 3)]
Urban Computing

- **A definition:**
  - The integration of computing, sensing, and actuation technologies into everyday urban settings and lifestyles.

  [source: IEEE Pervasive Computing, July-September 2007 (Vol. 6, No. 3)]

- **Urban settings** include, for example, streets, squares, pubs, shops, buses, and cafés - any space in the semipublic realms of our towns and cities.

- Only in the last few years have researchers paid much attention to technologies in these spaces.

- **Pervasive computing** has largely been applied
  - either in relatively homogeneous rural areas, where researchers have added sensors in places such as forests, vineyards, and glaciers
  - or, on the other hand, in small-scale, well-defined patches of the built environment such as smart houses or rooms.

- **Urban settings are challenging** for experimentation and deployment, and they remain little explored.
Stream Reasoning for Urban Computing

An example: variable Tolling in Urban Area

- Toll notification
- Accident Detection
- Accident notification
- Travel time
- Streamed Input
- Stream Reasoner
- Stored Result
- Selective Memory
- Toll Policy

Registered query:

- Toll notification
- Accident Detection
- Accident notification
- Travel time
- …

Semantic lifter:

- Streamed Input
- Models
- Rules
- Toll Policy