DejaVu: A Complex Event Processing System for Pattern Matching over Live and Historical Data Streams

Nihal Dindar, Peter M. Fischer, Nesime Tatbul @ ETH Zurich

Motivation

- Find patterns on both live and archived data streams as well as detecting correlations among them
- **Use cases:** financial data analysis, healthcare monitoring, supply chain management, etc.

Goals

Design and implement a CEP system that
- **detects and correlates patterns**
- works over both **live and historical events**
- provides a **uniform declarative query interface**
- scales to **high throughput for high-volume streams**

DejaVu Query Processing Engine

- Extends **relational database engine** MySQL by
  - **pattern matching** (semantic windows)
  - **continuous query** life cycle
- Pattern expressions **composable with SQL**
- **Automata-based** pattern computation
- Optimizations to reduce pattern matching cost
  - input sharing
  - state minimization
- Supports **Pattern Correlation Queries (PCQs)**
  - formal semantics
  - architectural extensions
  - cost model and optimizations

Optimizing PCQ Processing

- Cost -model based optimizations, both **architectural and algorithmic**:
  - pattern computation before live-archive correlation
  - lazy archive pattern computation
  - recent input buffering
  - query result caching
  - join source ordering

- **Throughput improvements** up to 2 orders of magnitude

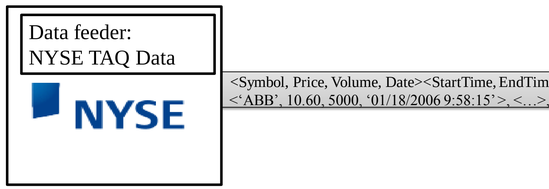
SQL-based Uniform Query Language[1]

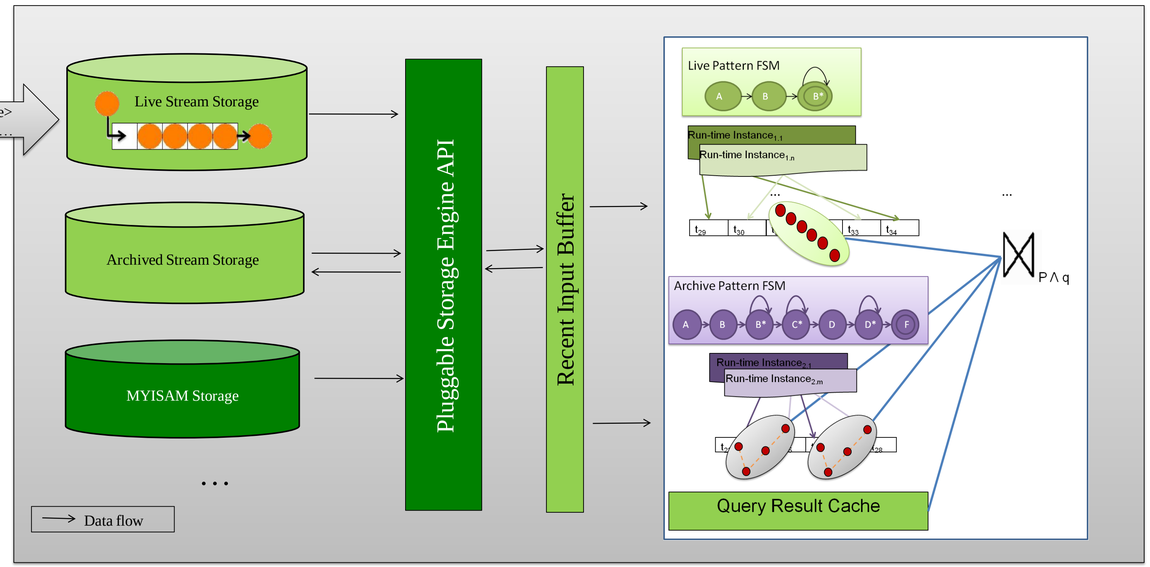
```
SELECT symbolL, initPriceL, minPriceL, initPriceA, …
FROM
  StockLive MATCH_RECOGNIZE (
  PARTITION BY symbol
  MEASURES A.symbol AS symbolL, A.price AS initPriceL,
                LAST(B.price) AS minPriceL
  ONE ROW PER MATCH
  AFTER MATCH SKIP TO NEXT ROW
  INCREMENTAL MATCH
  PATTERN(A B+)
  DEFINE /* A matches any row */
          B AS (B.price < PREV(B.price))),
  StockArchive MATCH_RECOGNIZE (
          …. // Tick-shaped in stock price
WHERE symbolA = symbolL
RECENCY = 7 seconds;
```

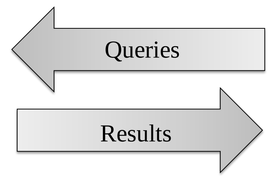
Fall in stock price

Correlation of live and archive patterns

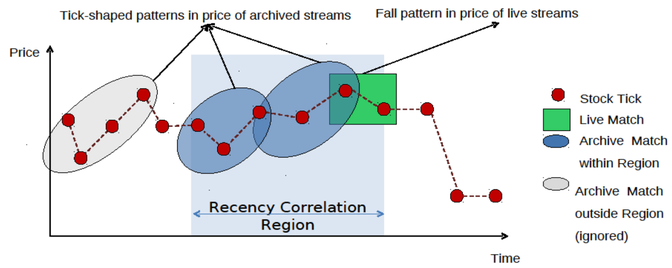
[1] Anonymous, "Pattern Matching in Sequences of Rows", http://askTom.oracle.com/tkyte/row-pattern-recognition-11-public.pdf , March 2007.







DejaVu client



Upon detecting a **fall** in the current price of stock X on the live stream, look for a **tick-shaped** pattern for X within recent archive.

Live Stream Storage

- **In-memory** storage engine for **incoming streams**
- Support for pull and push modes

Archived Stream Storage

- **On-disk** storage engine for **archived streams**
- Append-only, order-preserving, indexes

Recent Input Buffer

- **Cache** for efficient access to **recent stream data**
- Bulk inserts into archive stream storage

Push-based Mode & Adaptive Switch

- Execution can adapt between
  - **push:** new data pushed into the Input Holders
  - **pull:** query processor requests data on demand

- **Adaptivity** driven by
  - query processor load
  - queue lengths

Query Result Cache

- Caches archive matches to **avoid re-computation** of archive patterns
- Significant performance benefits when recency correlation regions overlap
- Size at most linear to the size of the recency region (fits into memory in most cases)

Performance on NYSE TAQ Data