Temporal Reasoning for Events in a Knowledge-based Network

Clay Stevens, Supervisors: Declan O'Sullivan, John Keeney

Introduction

Project Motivation
- Increased need for real-time complex event processing
- Must be distributed, scalable, and expressive
- Most event-based systems are not

Project Approach
- Extend a knowledge-based networking system
- A persistent data store component
- New temporal and composite operators
- Design and implement within the KBN
- Test the scalability
- Explore the expressiveness

Complex Event Processing

CEP Overview
- Filter a continuous event stream
- Find composite events
- Correlate atomic or composite events into patterns
- Active databases or middleware systems

Composite Events
- Patterns of atomic events
- Aggregated or composed
  - Logical compositions (conjunction, disjunction, etc)
  - Temporal relationships

Event Correlation
- Correlates events based on their causal structure
- Can also use spatial or temporal relationships between events

Temporal Reasoning

<table>
<thead>
<tr>
<th>Condition</th>
<th>Operator</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>X meets Y</td>
<td>Basic</td>
<td>Substring</td>
</tr>
<tr>
<td>X overlaps Y</td>
<td>Basic</td>
<td>Substring</td>
</tr>
<tr>
<td>X during Y</td>
<td>Temporal</td>
<td>Substring</td>
</tr>
<tr>
<td>X meets Y</td>
<td>Semantic</td>
<td>Semantics</td>
</tr>
<tr>
<td>X overlaps Y</td>
<td>Semantic</td>
<td>Semantics</td>
</tr>
<tr>
<td>X during Y</td>
<td>Semantic</td>
<td>Semantics</td>
</tr>
<tr>
<td>X starts Y</td>
<td>Semantic</td>
<td>Semantics</td>
</tr>
<tr>
<td>X finishes Y</td>
<td>Semantic</td>
<td>Semantics</td>
</tr>
</tbody>
</table>

Data Store Design

- Simple publication/attributes store
- Performs all storage and query functions
- Implemented vendor specific versions (Oracle, MySQL)

Data Types
- Integer, float, string, boolean, bag (multiset)

Operators
- Basic: numerical ordering, string prefix and suffix, substring
- Bag: equal bag, subbag, superbag, composite bag operator
- Semantic: semantic equivalence and non-equivalence, “is-a”, “is not a”, sub- and super-class and property, ontological property

Knowledge-based Networks

KBN Overview
- Semantic extension to content-based networking
- Routes messages to subscribers based on the message content and semantics
- Employs an external ontological reasoner (e.g., Jena) for semantic operators

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Evaluation and Case Studies

Test Results
- Processing time increases linearly with number of returned events
- Scales linearly with result set size
- Filter operator performance grows with limit on result set

Case Studies
- Severe weather reporting service
  - Provides timely, accurate reports on severe weather
  - Uses the temporal operators, spatial ontology
  - Automatic log-level refining
  - Changes logging level based on event patterns
  - Easily performed using AFTER operator

M.Sc. in Computer Science
(Networks and Distributed Systems)