Stream and Complex Event Processing

Learning From the Past

Automatic Rules Generation for CEP

G. Cugola    E. Della Valle    A. Margara

Politecnico di Milano

cugola@elet.polimi.it
dellavalle@elet.polimi.it

Vrije Universiteit Amsterdam

a.margara@vu.nl
Complex Event Processing (CEP)

sources → Complex Event Processing → rules → sinks

- Stream & Complex Event Processing - Automatic Rules Generation for CEP
Idea
Outline

• Model
• Prototype implementation
  • Based on machine learning
• Initial results and validation
Event Model

Temperature @10
(room=123, value=24.5)

S()

T(25)  T(27.5)  T(28)  T(50)
Rule Languages

- NextCEP
- Oracle CEP
- TIBCO Business Events
- Stream Mill
- Microsoft Stream Insight
- SASE+
- Borealis
- Aurora
- Stream
- CQ
- Esper
- Telegraph
- Cayuga
- TESA
- Progress Apama
- ETALIS
- IBM WSEBE
- Padres
Define FIRE:
within 5 min
{ Smoke() and Temp(value>40) and not Rain (mm>2) } 
where { Temp -> Smoke }

CEP Operators

Window

Combination

Selection

Sequence

Negation
iCEP

<table>
<thead>
<tr>
<th>Requires {}</th>
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<tbody>
<tr>
<td>Optional { Size of Window }</td>
<td>Optional { Relevant Events/Attributes }</td>
</tr>
<tr>
<td>Events and Attributes Learner</td>
<td>Window Learner</td>
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<td>Produces { Events/Attributes }</td>
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Machine Learning

Var1 = 25; Var2 = True; .......; Occurred = YES

Var1 = 35; Var2 = True; .......; Occurred = YES

Var1 = 12; Var2 = False; .......; Occurred = NO

Var1 = 25; Var2 = False; .......; Occurred = NO
iCEP

- Events and Attributes Learner
  - Requires: {}
  - Optional: { Size of Window }
  - Produces: { Events/Attributes }

- Window Learner
  - Requires: {}
  - Optional: { Relevant Events/Attributes }
  - Produces: { Size of Window }

- Predicates Learner
  - Requires: { Events/Attributes, Size of Window }
  - Optional: {}
  - Produces: { Predicates }

- Sequences Learner
  - Requires: { Predicates, Size of Window }
  - Optional: {}
  - Produces: { Sequences }

- Negations Learner
  - Requires: { Predicates, Size of Window }
  - Optional: {}
  - Produces: { Negations }

Stream & Complex Event Processing - Automatic Rules Generation for CEP
Events and Attributes Learner

A = no; B = no; C = yes; D = yes; Occurred = no
A = yes; B = yes; C = no; D = no; Occurred = yes
iCEP

Stream & Complex Event Processing - Automatic Rules Generation for CEP
Window Learner

A = no; B = no; C = yes; D = yes; Occurred = no
A = yes; B = yes; C = no; D = no; Occurred = yes
iCEP

Stream & Complex Event Processing - Automatic Rules Generation for CEP
Predicates Learner

(v_a > 10 and v_a ≤ 12) or (v_a > 20)
iCEP

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**Events and Attributes Learner**
- Requires: {}
- Optional: { Size of Window }
- Produces: { Events/Attributes }

**Window Learner**
- Requires: {}
- Optional: { Relevant Events/Attributes }
- Produces: { Size of Window }

**Predicates Learner**
- Requires: { Events/Attributes, Size of Window }
- Optional: {}
- Produces: { Predicates }

**Sequences Learner**
- Requires: { Predicates, Size of Window }
- Optional: {}
- Produces: { Sequences }

**Negations Learner**
- Requires: { Predicates, Size of Window }
- Optional: {}
- Produces: { Negations }
Sequences Learner

• For each occurrence of CE
• For each couple of events e1 and e2
  • Count $\text{Freq} (e_1 \rightarrow e_2)$
  • Count $\text{Freq} (e_2 \rightarrow e_1)$
• $\text{Seq}(e_1, e_2)$ iff
  • $\text{Freq} (e_1 \rightarrow e_2) \approx 1$
  • $\text{Freq} (e_1 \rightarrow e_2) \gg \text{Freq} (e_2 \rightarrow e_1)$
iCEP

Stream & Complex Event Processing - Automatic Rules Generation for CEP
Negations Learner

- For each occurrence of CE
- For each relevant event $e$
  - Count the $\text{Freq}(e)$
- $\text{Neg}(e)$ iff
  - $\text{Freq}(e) \approx 0$
**Evaluation**

- Generate evaluation history of primitive events
- Generate training history of primitive events
- Detect all composite events in training history
- Split training history in positive and negative traces
- Execute iCEP to infer Rule R*
- Compare rules syntactically
- Detect all composite events in evaluation history using R*
- Detect all composite events in evaluation history using R
- Compare rules to determine recall and precision
## Evaluation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Event Types</td>
<td>25</td>
</tr>
<tr>
<td>Distribution of Types</td>
<td>Uniform</td>
</tr>
<tr>
<td>Number of Attributes per Event</td>
<td>1</td>
</tr>
<tr>
<td>Number of Values per Attribute</td>
<td>100</td>
</tr>
<tr>
<td>Number of Sequences</td>
<td>1</td>
</tr>
<tr>
<td>Length of Sequences</td>
<td>3</td>
</tr>
<tr>
<td>Average Window Size</td>
<td>10</td>
</tr>
<tr>
<td>Number of Negations</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recall</th>
<th>Precision</th>
<th>Type</th>
<th>Win</th>
<th>Pred</th>
<th>Seq</th>
<th>Neg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.99</td>
<td>0.94</td>
<td>0.1</td>
<td>3.6</td>
<td>0.03</td>
<td>0.2</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Number of Events

W/ Sequence

W/O Sequence

Stream & Complex Event Processing - Automatic Rules Generation for CEP
Window Size

![Graph showing the relationship between window size and recall/precision. The graph plots recall and precision against different window sizes, indicating a decrease in precision and a slight decrease in recall as window size increases.](image-url)
Number of Types

![Graph showing the relationship between the number of event types and recall and precision. The graph includes error bars and a legend indicating Recall and Precision.]
Number of Samples

![Graph showing recall and precision against number of samples (k)]
Open Questions

• How to encode multiple-attributes?
• How to encode parameters?
  • Relations between the values in the same or different events
  • E.g. Smoke and Temperature must share the same location