A Survey of Complex-Event Processing Models

Charles Young
Principal Consultant

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Agenda

- Understanding CEP
- CEP Technologies
  - Event Stream processing
  - Exploiting Rete for CEP
- Event Processing Networks
Books

David Luckham

Opher Etzion
Peter Niblett
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http://complexevents.com/

http://epthinking.blogspot.com/
Complex Events

Event Cloud (poset)

Simple Events

Causality

Rules / Queries

Pattern Matching

CEP

Complex Events
CEP Applications

- Multi-sensor Data Fusion
- Sense and Respond
- Situational Awareness
- Predictive Analytics
- Observe-Orientate-Decide-Act (OODA)
- Fraud Detection
- Intrusion Detection
- Algorithmic Trading
- RFID Processing
- Regulatory Compliance
- Diagnostics
Event Abstraction Hierarchies

- Map from simpler to more complex events at multiple levels
- Provide views for different personas
Requirements for CEP Technology

- Interaction with Event Clouds
  - Event sensing and observation
  - Event representation
  - Event transport & adaptation
  - Event semantics
  - Out-of-order event handling

- Event Pattern Recognition
  - Pattern matching
  - Continuous processing
  - Event scoping
  - Event abstraction hierarchies
  - Negation

- Performance & Scalability
  - Sustainable throughput
  - Situational awareness and visualisation
  - Decision management
  - Parallelism
  - Simulation
  - Insight & debugging
CEP Agents

Event Cloud → Sense → Deliver → Adapt_{in} → Detect → Reify → Adapt_{out} → Relay → Next EPA, external system or store, event broker, etc.

CEPA

Rules

Context

{act}
Event Processing Networks (EPNs)
Event-Driven Architecture

- Back Office Systems
- LoB Applications
- Financials / ERP
- External Organisations / Trading Partners
- Cloud Services

SOA / Service Bus

Business Rules

Workflow

Automated Business Processes

Business Services

Integration Services

Context

Event Cloud

Sensor Management

EPN Management

EPN Configuration

EPN Monitoring

Event Stores

Event Delivery

Agent

Agent

Agent

Abstract Event Clouds

Event Abstraction

Deployment

Code and Model Repositories

Development Tools

Event Modelling

Application Lifecycle Management

Simulation

Governance

Visualisation

Analytics

Notification
Event Stream Processing

- Stream-Orientated
- Set-Based
Set-Based Operators

Stream – to – View

1 - \infty

View – to – View

View – to – Stream
Simple Stream Processing in EPN

Event Cloud

Sense

Filter

Simple EPA

Detect & Reify

CEP

CEPA

Abstract Event Cloud
Select and Consume

- Context
  - Timestamps
  - Temporal Windows
  - Template Instantiation
Event Pattern Languages

- Production Rules
- ECA Rules
- Dataflow DSLs
- Extended SQL
- Script / GPL
  - Imperative
  - Declarative (functional)
Rete: Stream vs. Set

α-network

β-network

β-node
Right Activation

β-memory
Token B1
Token B2
Token B3

α-memory
WME A1
WME A2

β-node
Left Activation

β-memory
Token A2 B1
Token A1 B2
Token A1 B3
Token A2 B1
Token A2 B3

Look up

Stream-orientated

Synchronisation

Set-Based

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Rete as CEP Agent
Journey of Enlightenment

Enthusiasm

Peak of Rete Fundamentalism

Plateau of Peaceful Coexistence

Slope of Enlightenment

Trough of Disillusionment

CEP...What’s That?

With apologies to Gartner

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Rete and Event Stream Dataflows

- Maximises redundancy elimination
- Hard to change continuous queries dynamically
- Many synchronisation points
- Reduced benefit of parallelisation

- Minimal redundancy elimination
- Easier to change continuous queries dynamically
- Easier scaling through parallelisation
Other Issues

- Event semantics
  - Immutability
- Temporal Logic
- Selection and Consumption
- Handling out-of-order events
- Reasoning-under-uncertainty
Why use Rete in CEP?

- Stream Reasoning
  - ‘Downstream’ processing
  - Inference over events AND context data
  - Compute Event Abstraction Hierarchies

- Bridging the gaps
  - e.g.,
    - Event processing → Business Processes
    - Event processing → Analytics
Single Agents

- Event Stream (Simple)
  - Filtering events
  - Use close to event source
Single Agents

- Event Stream (CEP)
  - Ultra-low latency
  - High-throughput
Single Agents

- **Rete**
  - Inference over events and context
  - Use downstream of event sources
  - Parallelisation challenges
Combining Agents in an EPN

- Simple Event Streams Passed to Rete
  - Filter in Event Stream Agent
  - Aggregate & React in Rete Agent
  - Simple ECA model
  - Semantic Transformation
Combining Agents in an EPN

- Complex Event Streams Passed to Rete
  - Reduces Load on Rete Agent e.g., inference-only
  - Rete acts as ‘bridge’ to EDA
Combining Agents in an EPN

- Filter Events Inferred by Rete
  - Limited Applicability
  - Filtering historic events e.g., for simulation
Combining Agents in an EPN

- Detect Complex Events Inferred by Rete
  - Limited applicability
  - May be useful in analytics over historical data
Hybrid Agents

- Rete with Extended $\alpha$-network for Event Stream Filtering
  - Supports parallelisation for filtering
  - $\beta$-network sync
  - Garbage collection
  - ‘Unrestricted’
  - JBoss Rules

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Hybrid Agents

- Rete with CEP Detection Parallel to the α-network
  - Supports parallelisation filtering and aggregation
  - Maintain semantics
  - Complex high-level language design
  - Any benefit over separate agents?
Hybrid Agents

- Rete with Simple ECA Extensions
  - Limited applicability
  - No direct support for CEP!
  - Inversion of ECA
    - CEA?
    - No lazy-eval in Rete
  - Event $\rightarrow$ Activations
    \[1 - \infty\]
Hybrid Agents

- Rete with Complex ECA Extensions
  - ECA model with semantic separation (CEA)
  - Ultra low latency, lazy-eval CEP
  - Temporal restrictions on Rete
  - Complex language design
  - SAP Research, FZI
EPNs and ESBs

- Shared concerns
  - Common distributed ‘fabric’ and architecture
  - Centralised administration
  - Dynamic configuration and deployment
  - Platform and technology agnosticism
  - Dynamic routing and itineraries
  - Mediation
  - Adaptation
  - Monitoring
A Survey of CEP Models

Questions?
A Survey of CEP Models

Thank You