

Sense and Respond Systems for Crisis Management: The Event Web

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http://www.infospheres.caltech.edu/crisis_web/executive-summary.html

Infospheres Group: Dan Zimmerman, Brian Aydemir, Elliott Karpilovsky,
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iSpheres Corp.: Eric Bax, Greg Billock, Lee Rosen, Ian Swett

Outline

- Requirements for crisis management.
- Abstraction: The Event Web.
- Architecture of the Event Web
- Theory
- Prototype.
- Dagstuhl Workshop on Crisis Management: Feb 2004

- Work at Caltech and at iSpheres Corporation
- <http://www.ispheres.com>
- http://www.infospheres.caltech.edu/crisis_web/executive-summary.html



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2. A layer can be abstracted that represents these common problems.
3. Computer science theory and implementation practices can be applied to this layer.
4. **Software platforms for this abstraction can be tailored quickly to map to different crisis situations.**



We Cannot Plan for Every Contingency



- Crisis unfolds in unexpected ways.

Requirement: Configure sense and respond platform when crisis strikes; continuously reconfigure platform as crisis evolves.



Example



- Pilot radios from a plane that a passenger seems to have SARS symptoms.
- The plane crashes.



The Role of Time and Place



The response of an organization often depends on the history of a crisis, and not merely on its instantaneous state. Location plays an important role.



Relevance: respond to state trajectories and not merely to current state.



Example

- Time: Moving-point average of typhoid cases for 2 day window exceeds moving-point average over 1-month window, and, supply of antibiotics below threshold T.
- Location – Geographical information systems: Alert all vehicles moving towards a bridge.



Crisis Managers Need Attention Multipliers

Respond

Invoke distributed services
in real-time



Sense

Detect events across
extended environment in
real-time



Analyze

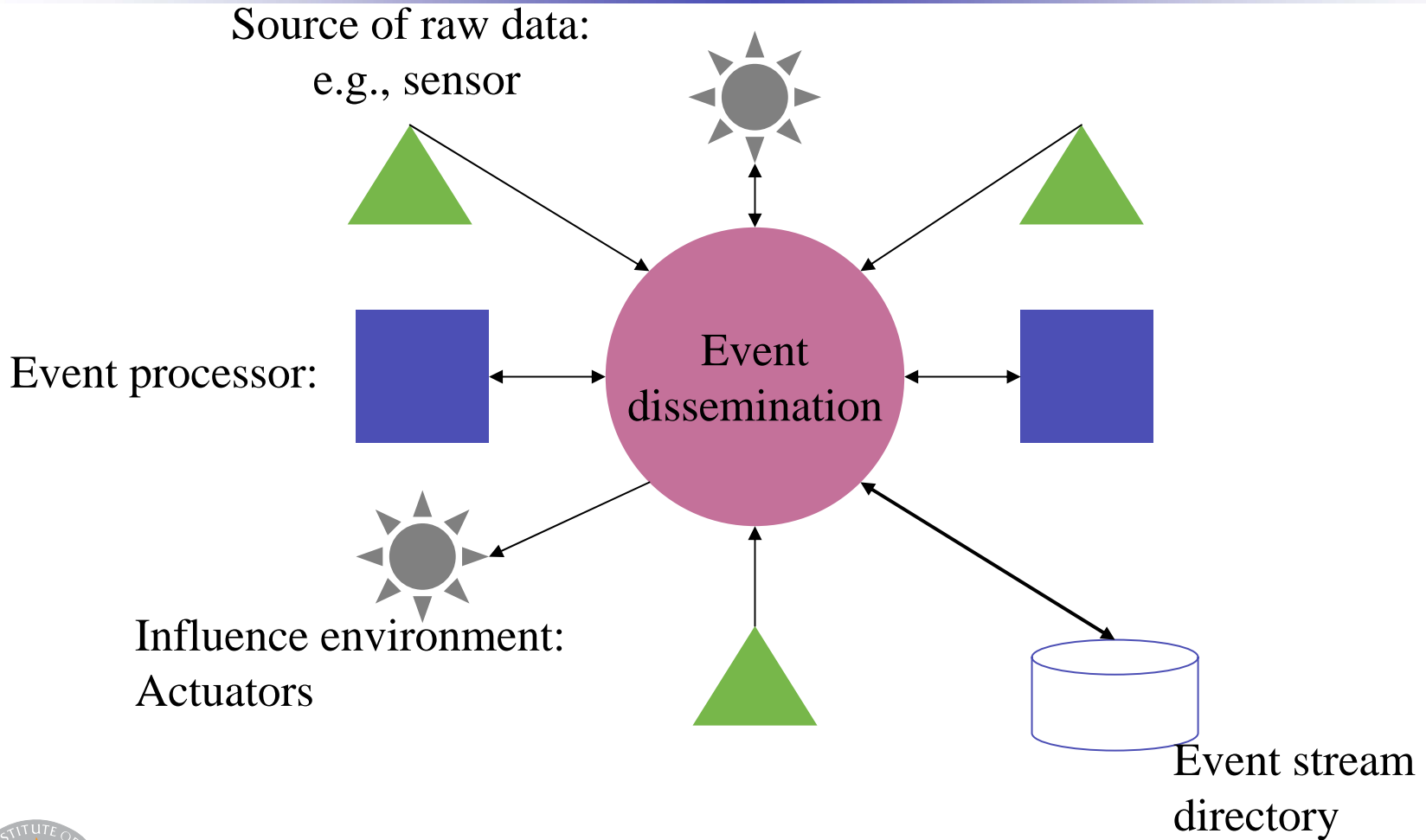
Aggregate events across multiple
sources

Friendly forces in area.
I am under attack

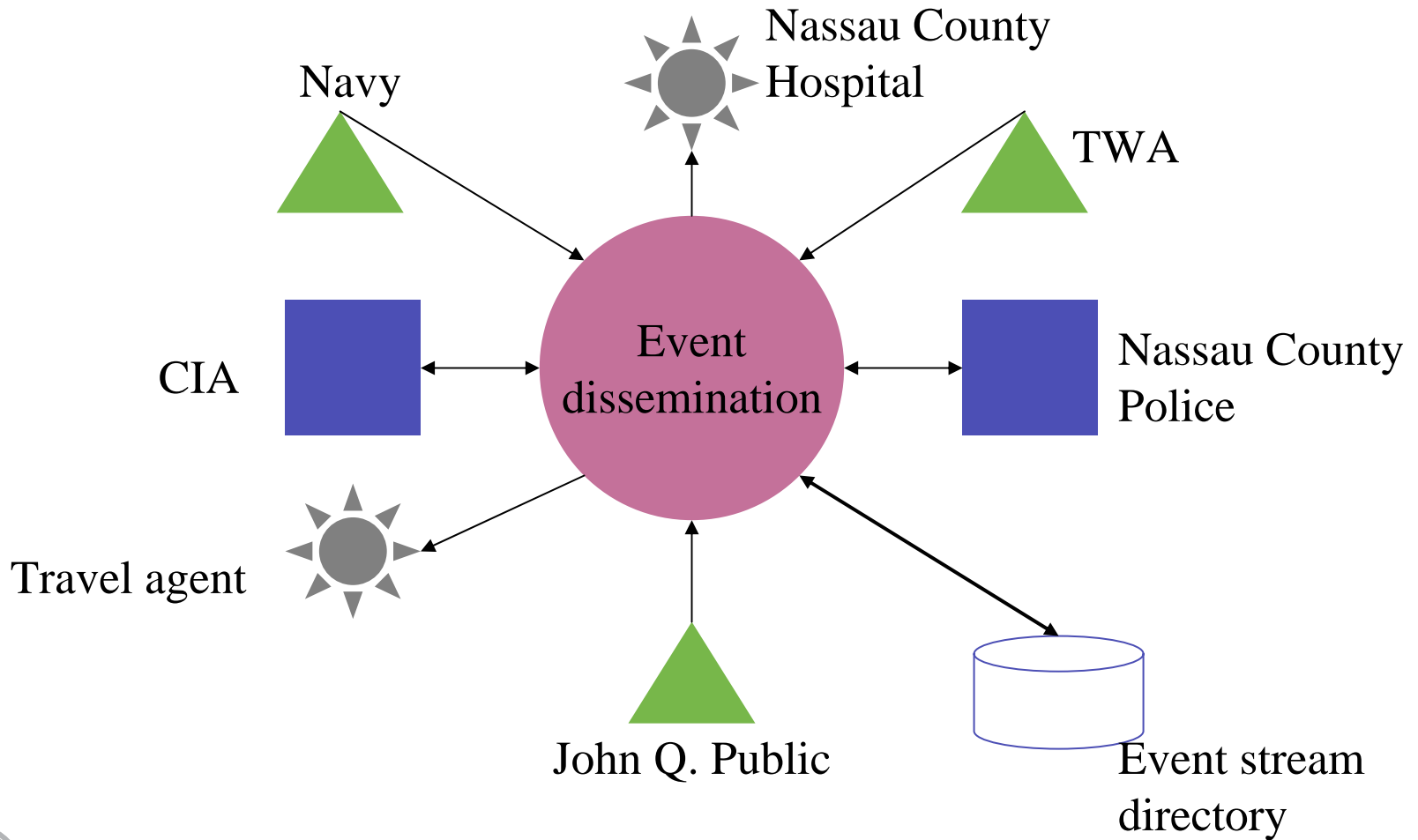


Sense and Respond Systems for Crisis Management
3 November 2003, Agent Based Modeling and Simulation

Architecture



Architecture



Central idea of architecture of Event Web

- Compositional.
 - Extensible component library.
 - Components can be added, deleted, modified during a crisis.
 - Components are loosely coupled.
-
- Communication between components: Events.



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Theory (time permitting)

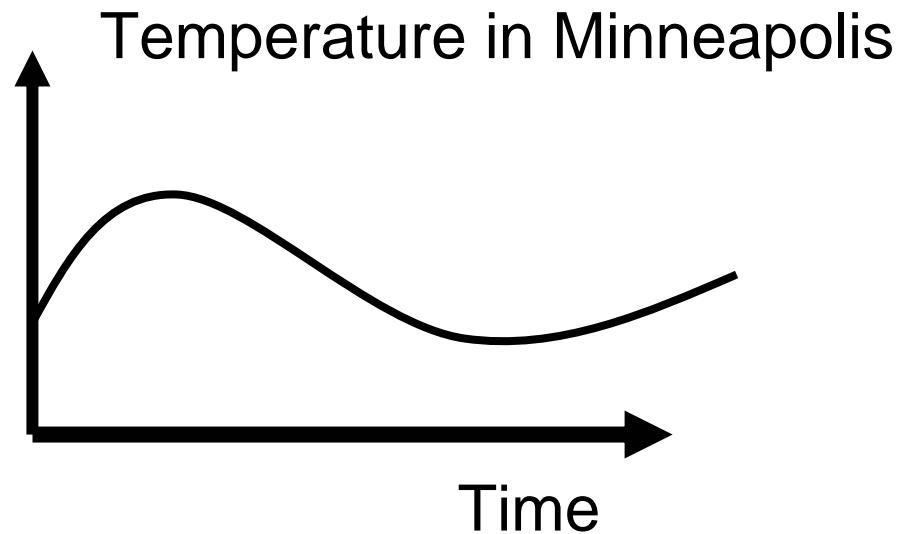
Semantics of events

- Error analysis
- Abstraction:
 - The programming paradigm: when-then rules.
- Stepwise refinement
 - global when-then rules to sets of sensors, actuators, and event processors with local when-then rules.
- Event notations
- Delta dataflow algorithm and chip design
- Incremental computation to process event streams.
- Optimization: intelligent sensors, capacity limitations,...



Types of events

An agent B generates an event to change other agents' estimates of the state of the environment.

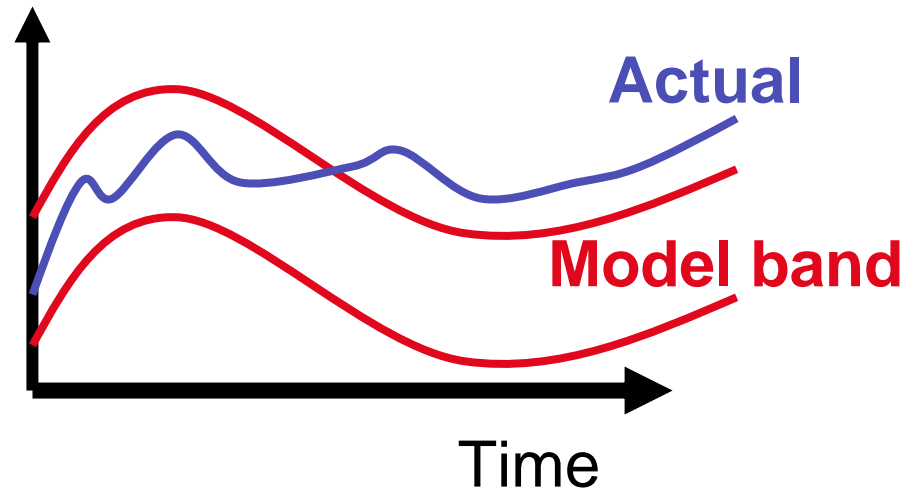


Model used by agent B of daily variation on Nov. 3



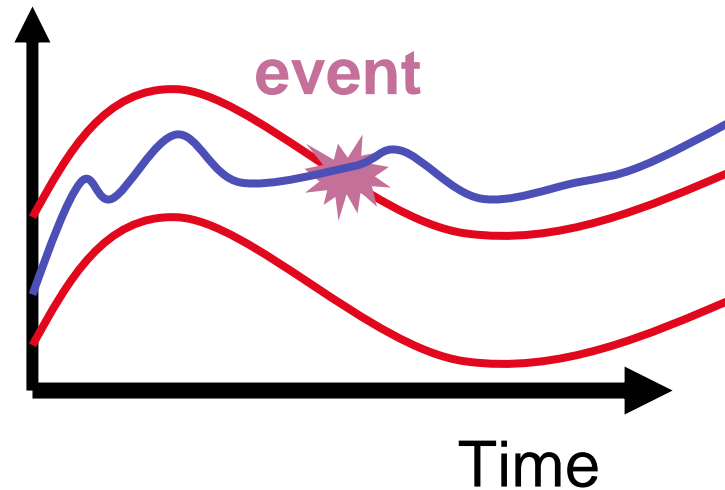
Events that changes estimates

An agent generates an event to change other agents' estimates of the state of the environment.



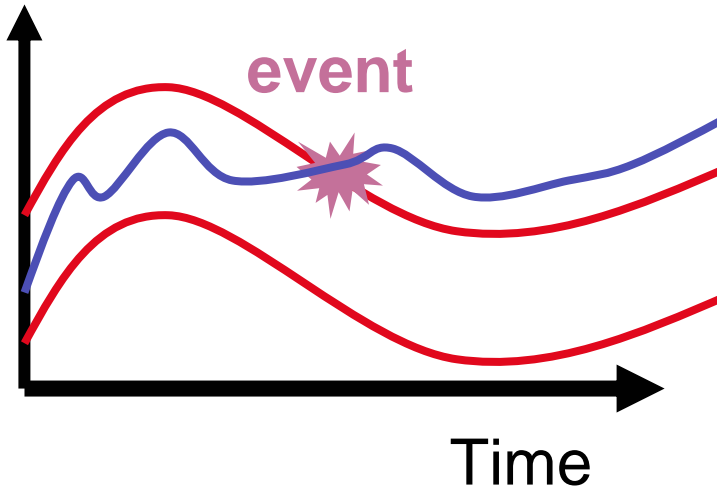
Events that change estimates

Agent generates an event to change “knowledge” or “estimates” of other agents.



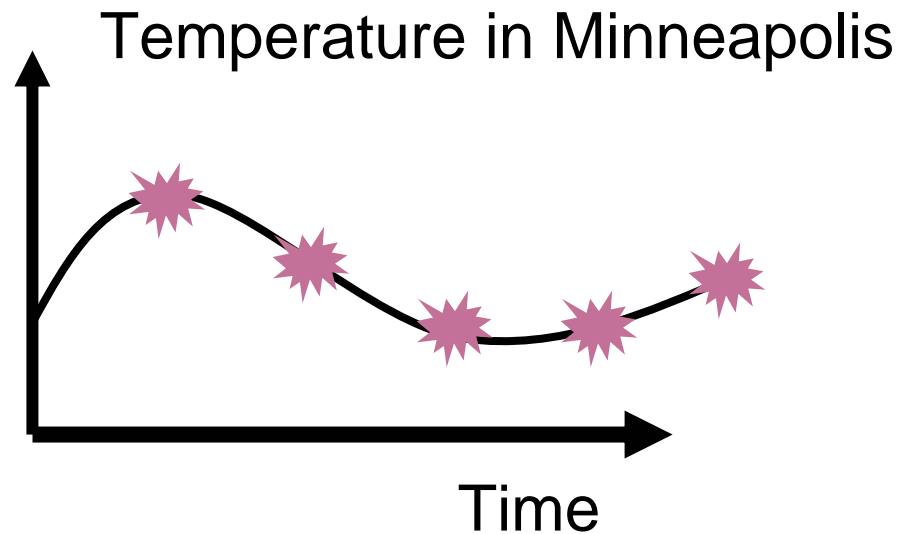
Events that change estimates

In this case, an event is encoded as a timestamp and a bit indicating whether the band was crossed above or below



Types of events: periodic events

An agent samples values according to a specified sampling strategy

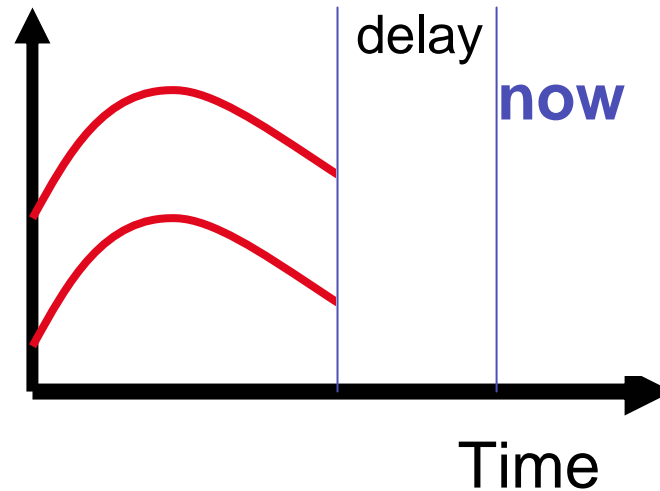


The model deals with the sampling strategy



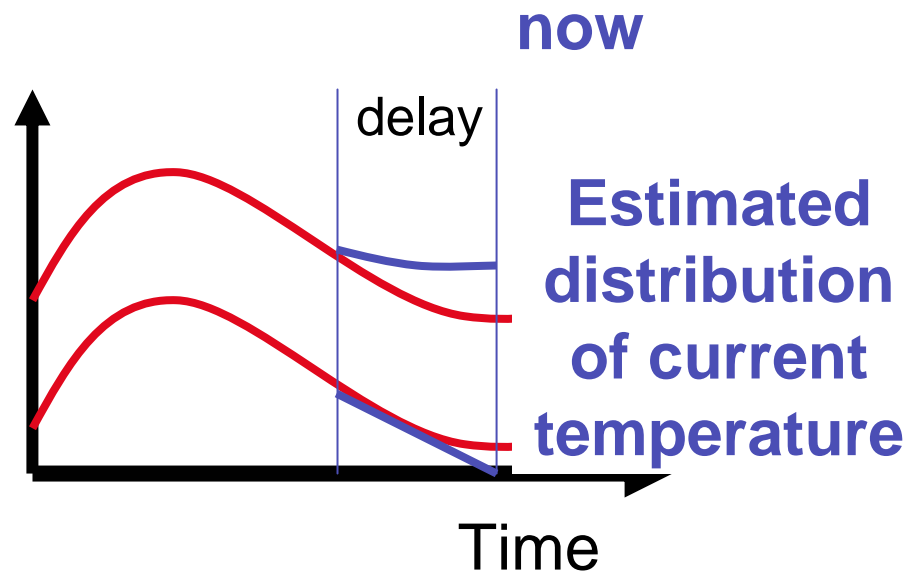
Errors due to delay

Receiving agents' estimation of state when no signal is received.



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Errors

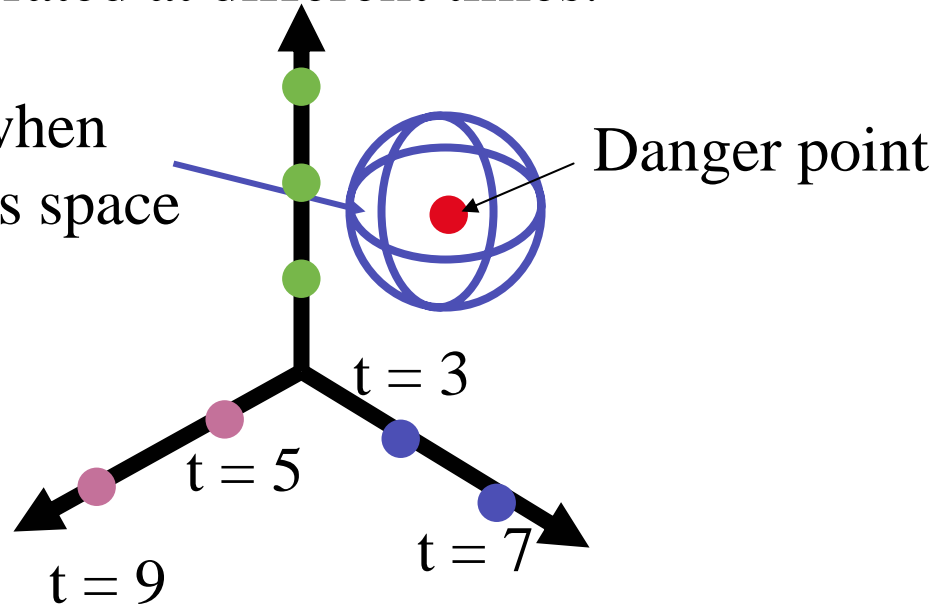
- Errors due to:
 - loss of events
 - delays
 - clock drift
 - erroneous monitoring of environment
 - erroneous computation



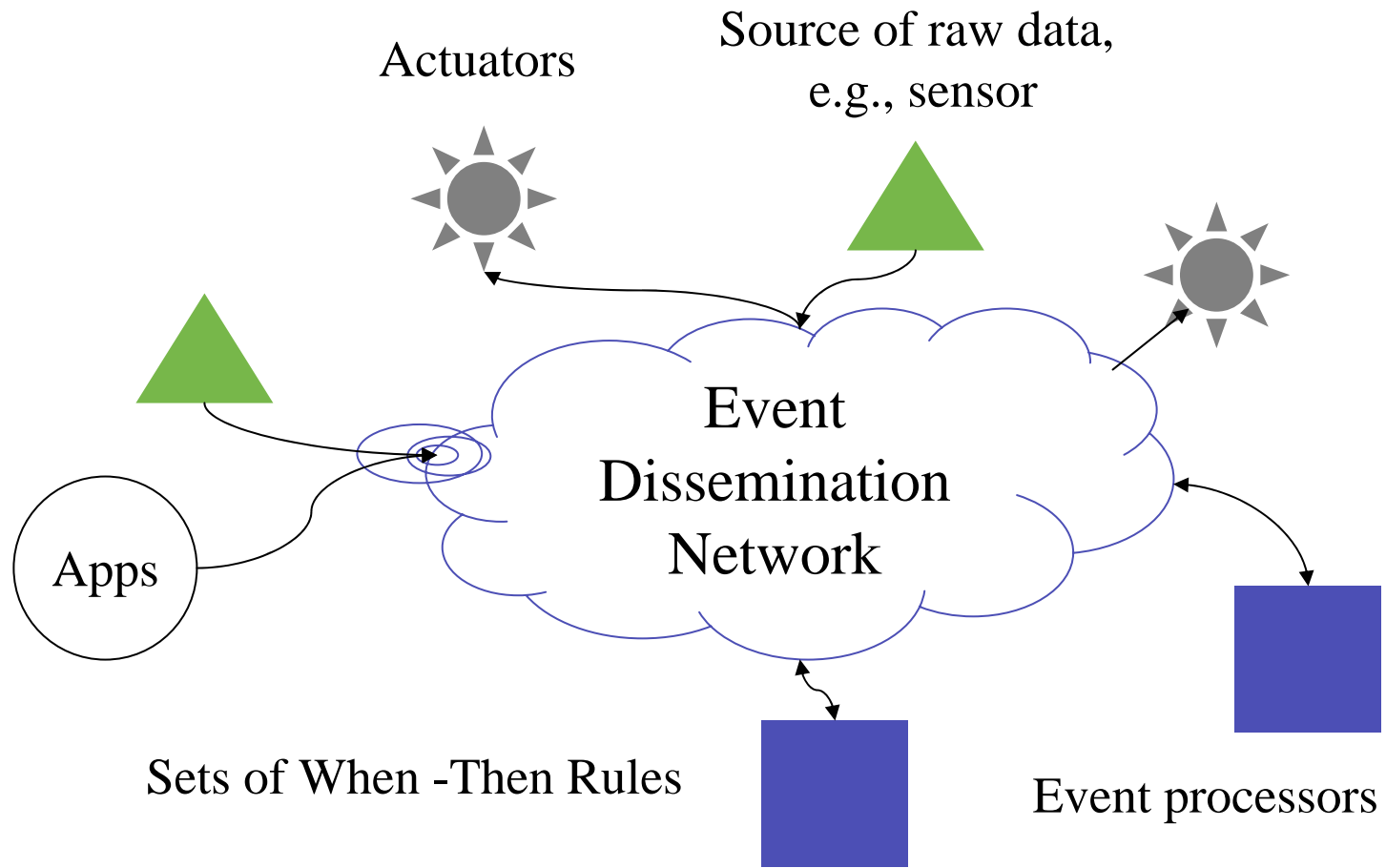
WHEN $f(\text{global_state})$ THEN generate event

- World is a multidimensional system with a huge number of dimensions.
- Information about different dimensions represented by discrete events generated at different times.

Generate event when system enters this space



The Event Web implements When-Then



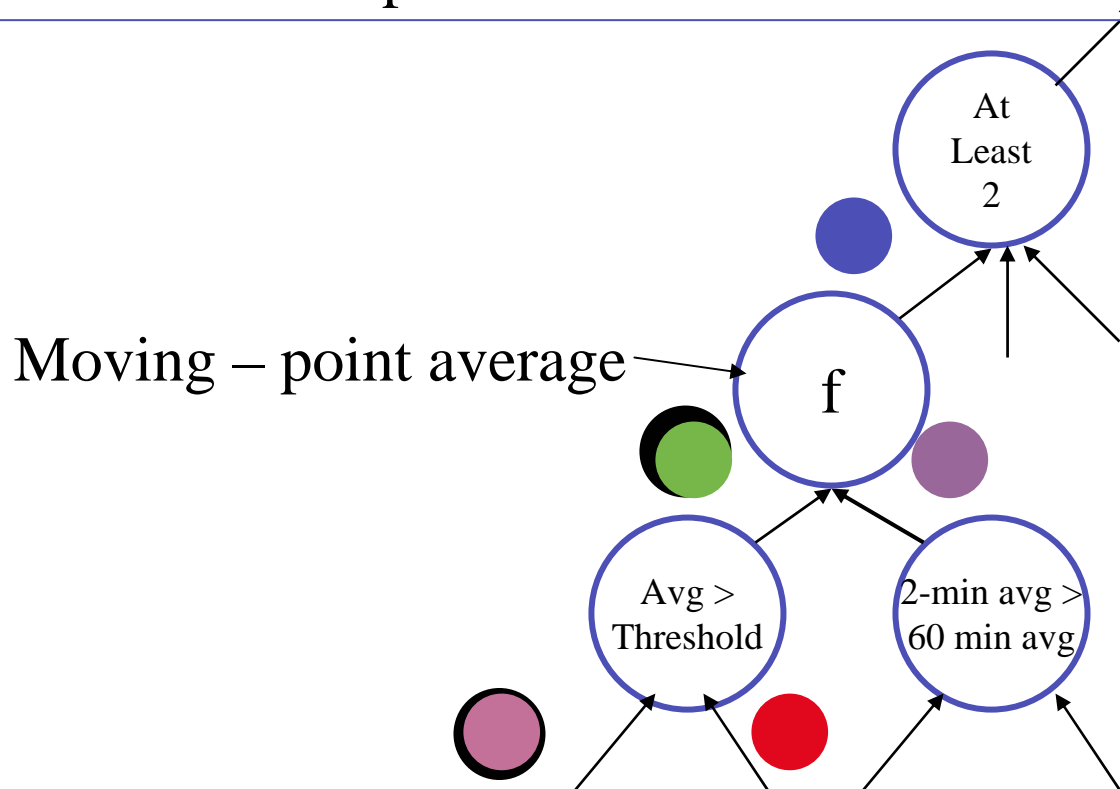
Stepwise Refinement

- Crisis manager specifies global when-then rules.
- Stepwise refinement to:
 - Sensors that generate raw events for the “when” predicate.
 - Event processors that execute local when-then rules.
 - Actuators that implement the final “then” action.
 - So that collectively the distributed system implements the global when-then rules.



Delta dataflow for executing when-then

Rajit Manohar, Cornell: building asynchronous VLSI chip for delta dataflow

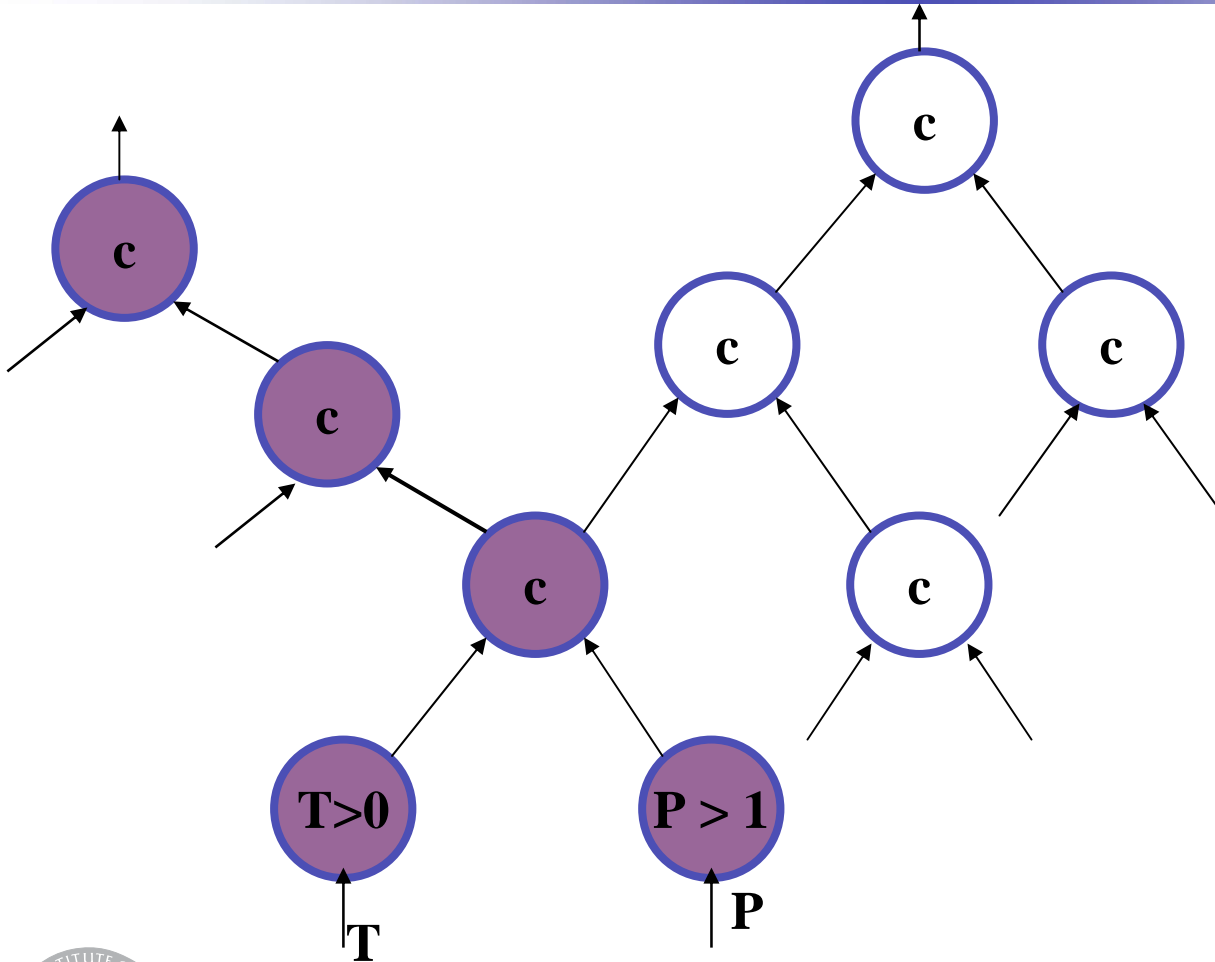


Notations for When – Then Rules

- Alternatives
- Same as query for a database: a rule is a persistent query.
 - `SELECT s WHERE b`
- General structure dealing with histories, geography, action sequences (e.g., time series, location sensitive, workflow representation)



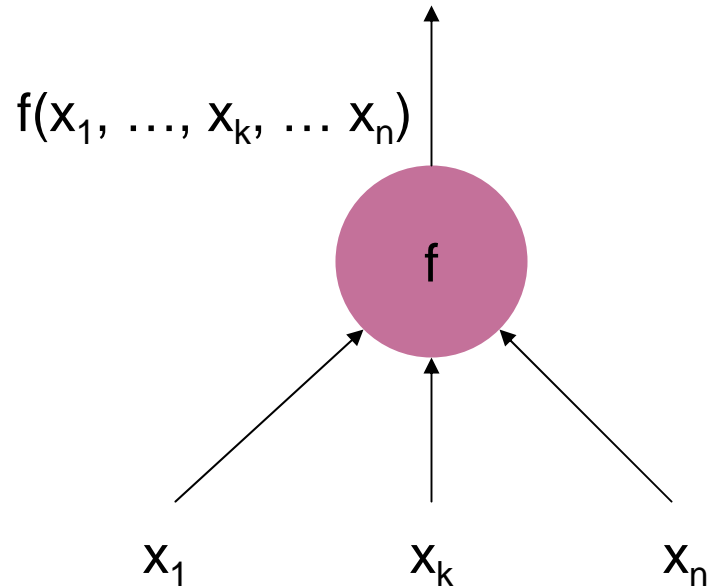
Incremental Compilation: Map Tree to Existing Node Structure on Some Machine



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Incremental Computation

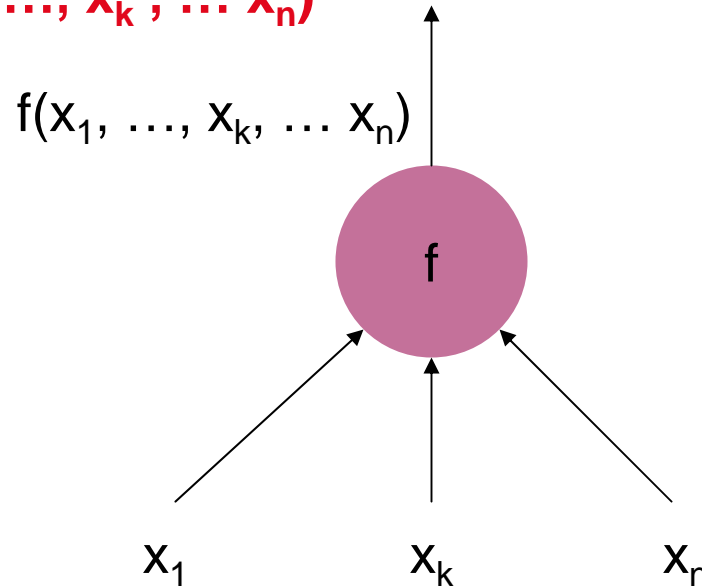


Change in value x_k'



Incremental Computation

New value: $f(x_1, \dots, x_k', \dots, x_n)$



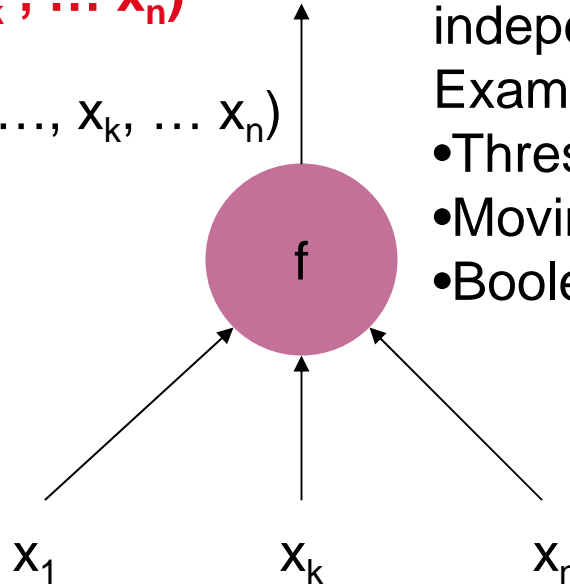
Change in value x_k'



Incremental Computation

New value: $f(x_1, \dots, x_k', \dots x_n)$

$f(x_1, \dots, x_k, \dots x_n)$



Change in value x_k'

Ideally, cost of computing $f(x_1, \dots, x_k', \dots x_n)$ from $f(x_1, \dots, x_k, \dots x_n)$ should be independent of n .

Examples:

- Threshold functions
- Moving-point computations
- Boolean operators



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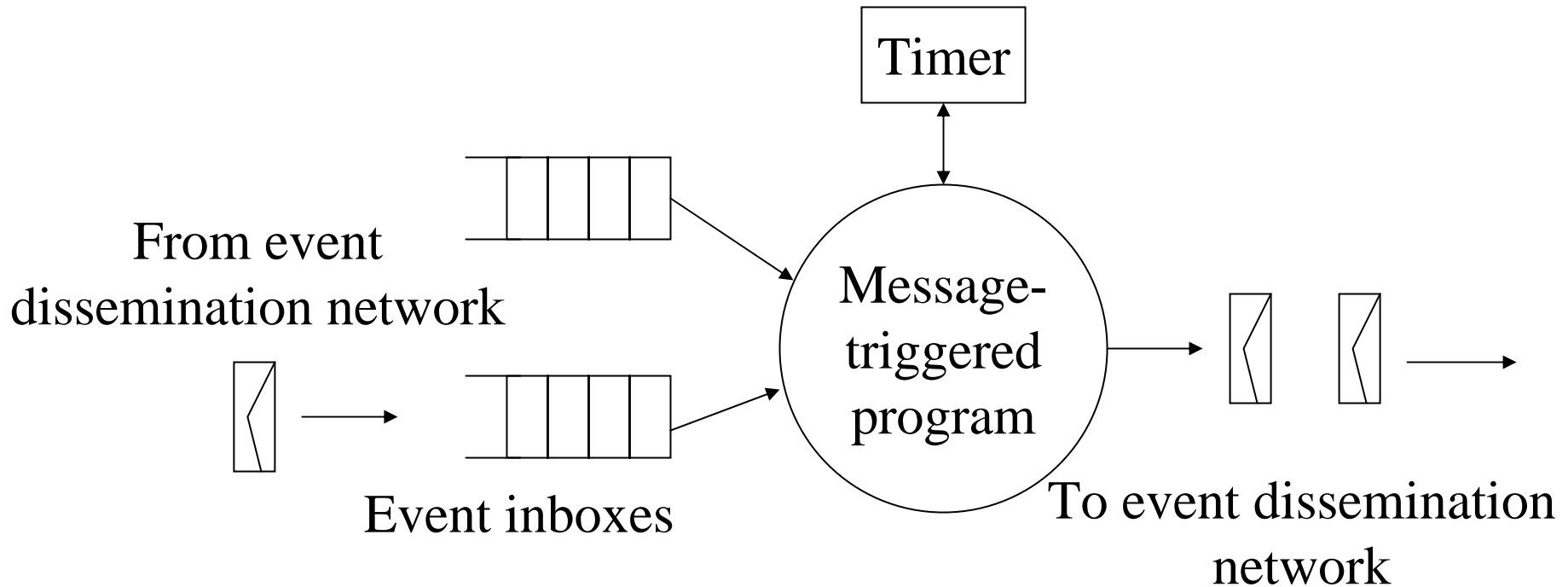


Prototype and product

- Goal: build a platform for implementing when-then rules.
- Show how global when-then rules can be refined automatically, or systematically by engineers, to obtain implementations.



Generic asynchronous node in Event Web



Prototype and product

- Event schema:
 - Caltech Infospheres prototype: XML document
 - iSpheres Corp product: Serialized Java object.
- Event dissemination
 - Infospheres: explicit subscription to event generator by event consumer
 - iSpheres prototype: subscription deduced from high-level notation.
- Event notation
 - Infospheres: only provides compositional structure
 - iSpheres: explicit notation for parametric and time series analysis.



Processing an Incoming Message

Incoming message



Current state
(XML doc)



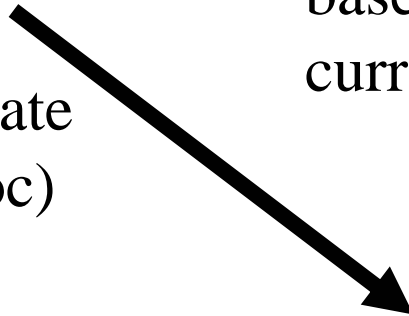
Processing an Incoming Message

Incoming message



Current state
(XML doc)

Choose XSLT transformation
based on incoming message and
current state



New state
(XML doc)



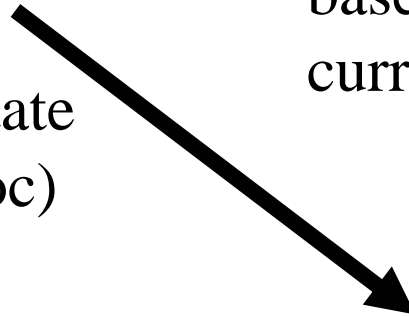
Processing an Incoming Message

Incoming message



Current state
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Choose XSLT transformation
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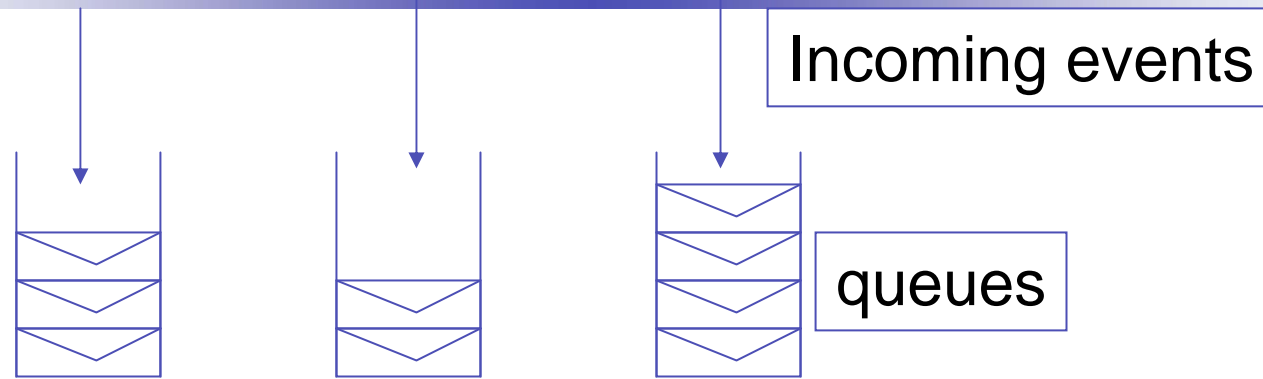


New state
(XML doc)

Sequence of outgoing
Messages (XML docs)



Architecture of event processor



Data structures shared by event queues and when-then rules engine

Rules execution



Related Work

- Events: David Luckham, iSpheres patent apps
- Content-based subscription: Gryphon, Sienna
- Real Time Business Intelligence
- Real Time Business Rules
- Active databases
- Gartner: Roy Schulte on Event-Driven Architecture
- **Download the iSpheres Sense and Respond platform from <http://www.ispheres.com>**



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