Probabilistic and Resilient Distributed Architectures

Sense and Respond Systems

Mani Chandy, Caltech

Joint Work With the Following at Caltech

- Dr. Sayan Mitra, Inf. Science & Tech (IST)
- Dr. Ryan McLean, Physics
- Annie Liu, CS
- Matt Wu, CS
- Michael Olson, CS
- Concetta Pilotto, CS

Overview

1. Probabilistic and Resilient Distributed Architectures: Sense and Respond Systems.

2. My message: CS is changing.

3. Examples of Sense and Respond Systems:
    1. Stopping Dirty Bombers
    2. Mobile agent formations
    3. Dashboards for politicians
    4. Management of the electrical power grid.

Sense and Respond Systems

Respond in a timely appropriate manner

Measures of Effectiveness of Sense and Respond Systems

The REACT metrics

1. Work required to use the system.
   A. Relevance
   B. Effort

2. Effectiveness of response.
   A. Accuracy
   B. Completeness
   C. Timeliness

3. Costs.

Accuracy

False warning

causes beaches to be evacuated

Example of inaccuracy: false warning or false positive.

Completeness

No warning

Example of incompleteness: no warning or false negative

Cost of no tsunami warning is measured in thousands of lives lost and billions of dollars of property damaged.

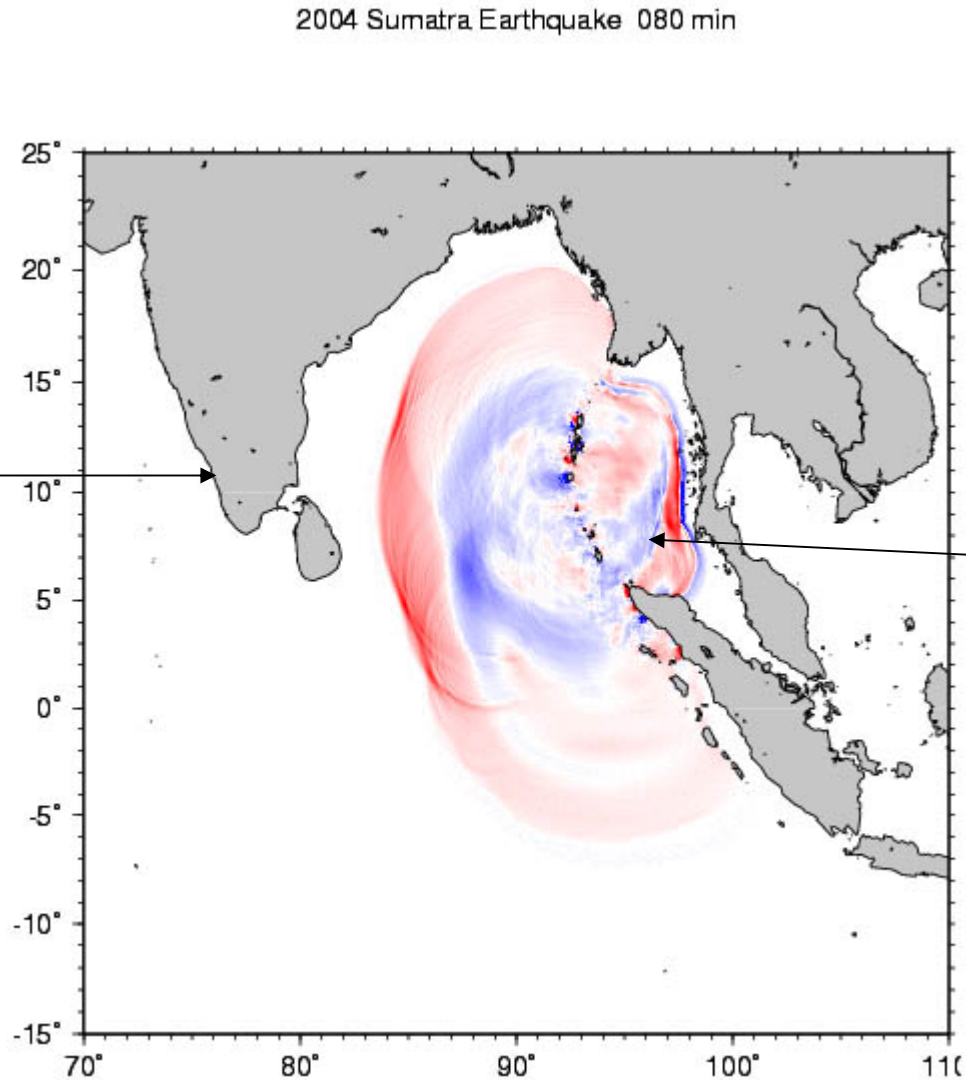
Timeliness

Late warning

Timely information enables effective response.

A one-hour tsunami warning has greater benefit than a one-minute warning.

Tradeoffs: Accuracy, Completeness, Timeliness, Costs



Lower cost system

Higher cost system

- Accuracy
- Completeness
- Timeliness

Overview

1. Probabilistic and Resilient Distributed Architectures: Sense and Respond Systems.

2. Changes in the computer science discipline ←

3. Examples of Sense and Respond Systems:
   1. Stopping Dirty Bombers
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Changing Emphasis: CS to IST

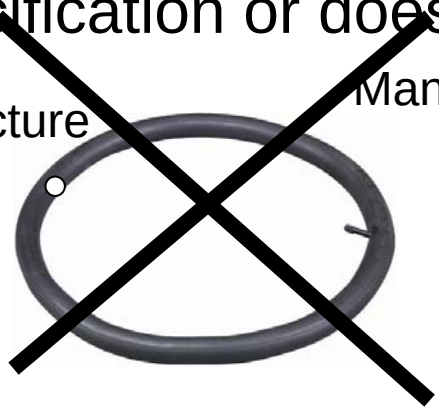
Paradigm for the greatest achievements in Computer Science: 1950 – 2008+ :

Binary: Works or doesn't work

1. Decidable or not decidable
2. Polynomial or non-polynomial
3. Program satisfies specification or doesn't satisfy spec.

Working tire

One puncture



Many punctures

CS Theory View of Correctness

Edsger Dijkstra:

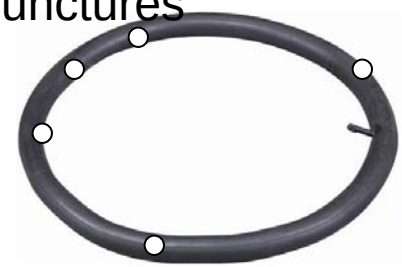
A tire that has no punctures is a functional tire.

A tire with punctures is non-functional regardless of the number of punctures

Working tire

One puncture

Many punctures



Increasing Emphasis: 2000 to 2020 +

- Errors are inevitable
- Timely reaction requires prediction
- Environment may be random and hostile
- More accurate, more complete information
- More appropriate response

- Paradigm is not binary but continuous:
  - good, better, best

Increasing Educational Emphasis in CS 2000 – 2020 +

- Information and computing in ubiquitous applications and multiple disciplines
  - Biology: systems biology, proteomics, genomics
  - Engineering: civil, controls, signal processing, sensor networks
  - Social science – economics, political science, finance

Increasing Educational Emphasis in CS 2000 – 2020 +

- Increasing educational emphasis on
  - Probability; optimization; control, decision & game theory.
  - Year-long term research projects for undergraduates that integrate multiple disciplines, e.g., protein folding and distributed computing.

Overview

1. Probabilistic and Resilient Distributed Architectures: Sense and Respond Systems.

2. Changing emphasis in design, theory and education:
   1. From CS to IST
   2. Logic to probability, game theory, social science

3. Examples of Sense and Respond Systems: ←
   1. Stopping Dirty Bombers
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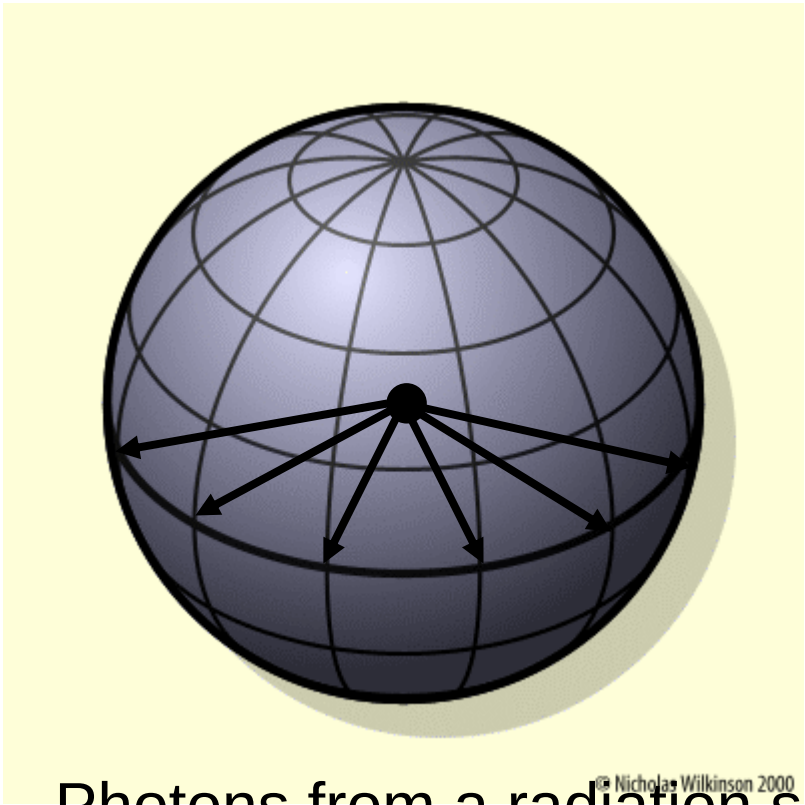
Stopping Radiological Terrorists in Critical Spaces

Sensors for Radiation Detection
Dr. Ryan McLean, Physics



Photons from a radiation source: Poisson process

Radiation Detectors Developed at Caltech Ryan McLean

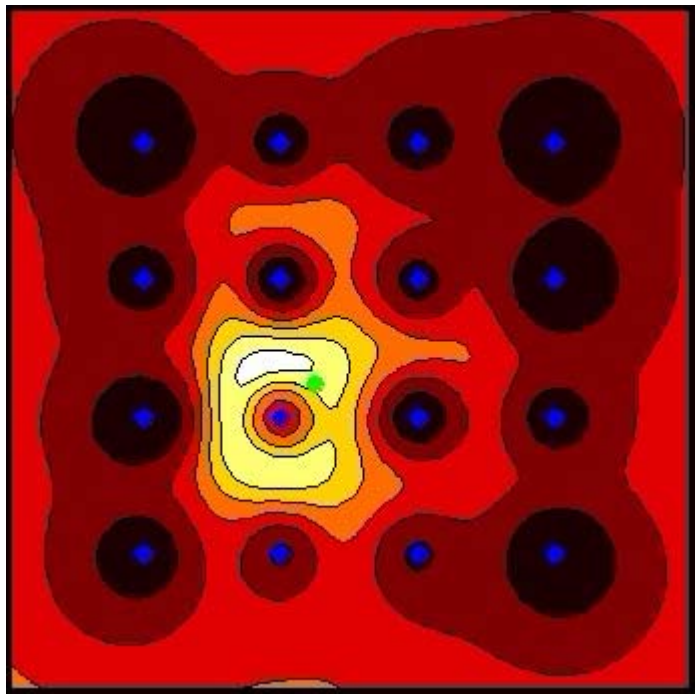
Problem: Optimum Placement of Sensors and Optimum Trajectory for Mobile Interdiction

Place sensors and batteries, or sensors with compute capability in traffic cones.
Optimal structure of deploying cones?

Attach sensors to street lamps getting power off the grid?

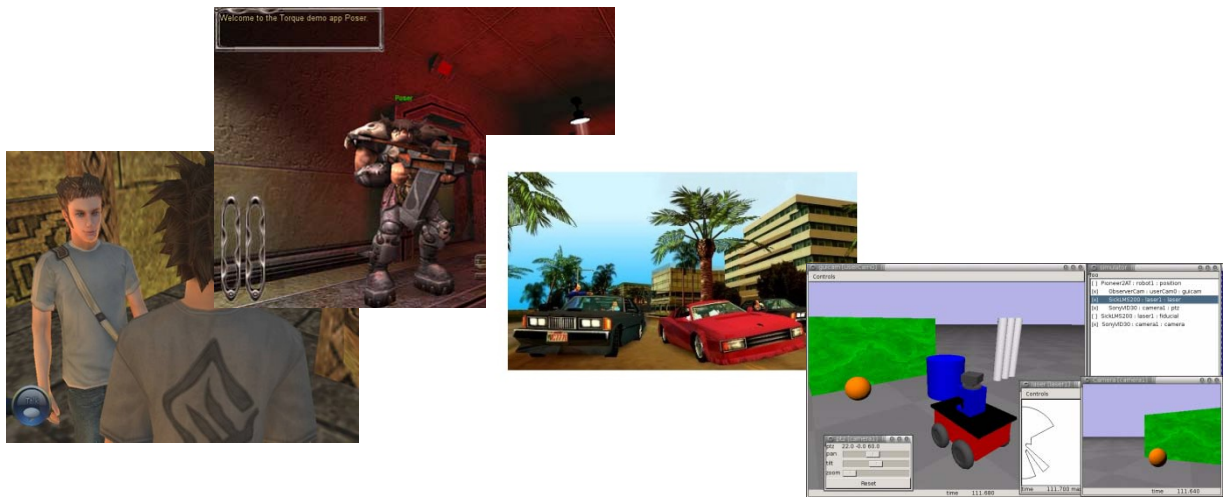
Sensors carried by security agents. What is their optimum trajectory?

Probability of Location of a Single Source: Concetta Pilotto, PhD Student, CS, Caltech



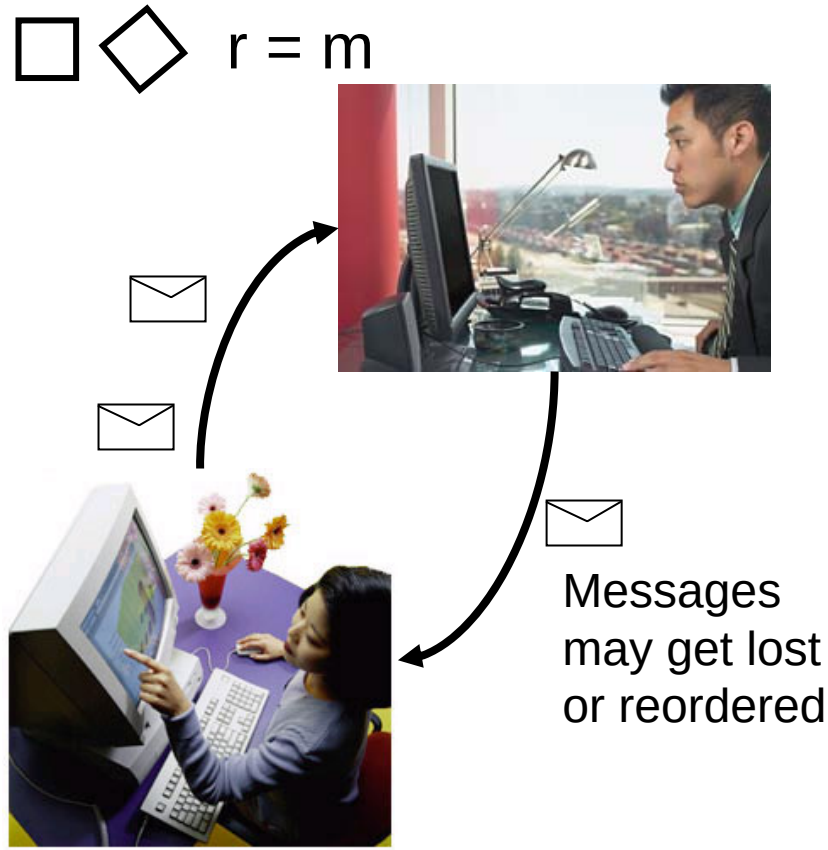
Defense Against Creative Enemies
Annie Liu, Matt Wu: PhD Students, CS, Caltech

- Our enemies may not behave the way we think they will.
- We developed systems in which security personnel play roles of law enforcement officers and terrorists to understand strategies.



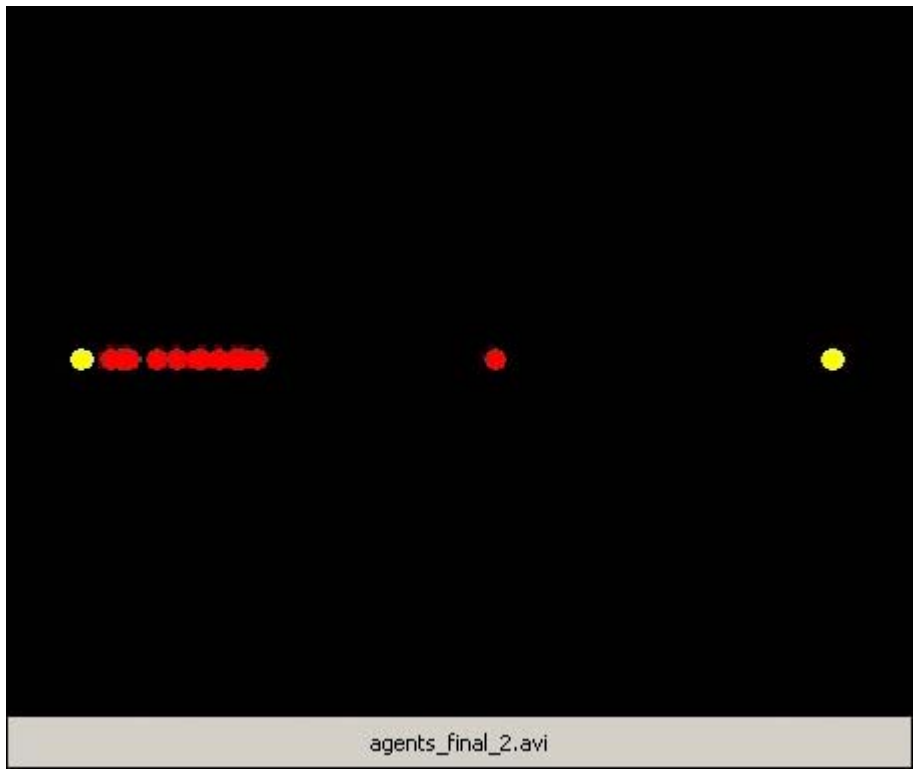
Interface of Controls and Computer Science
Dr. Sayan Mitra, IST Postdoctoral Fellow

$$\frac{\partial x_j}{\partial t} = c\sum_k (x_k - x_j)$$



Interface of Controls and Computer Science

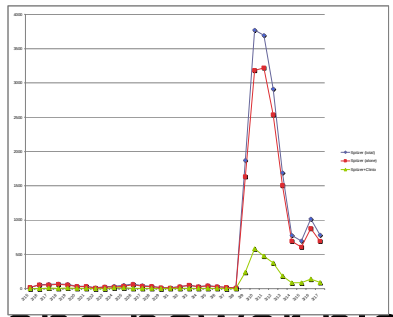
What do convergence, stability mean in systems with arbitrary message delay, loss?



Interfaces with Energy and Social Science

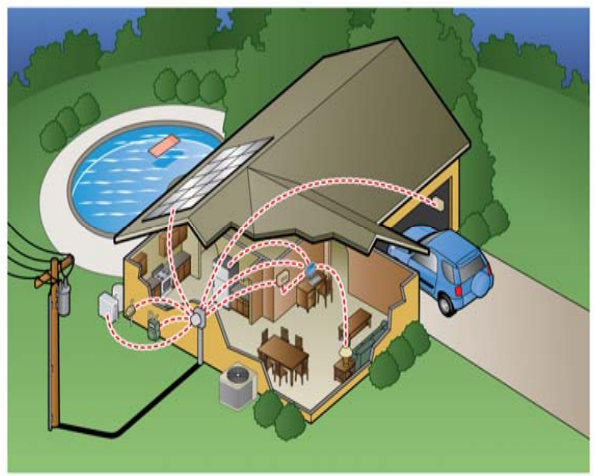
- Dashboards and Sense/Respond Systems for Politicians

Michael Olson, CS PhD Student, Caltech



- Managing energy consumption can save one power plant

Southern California Edison



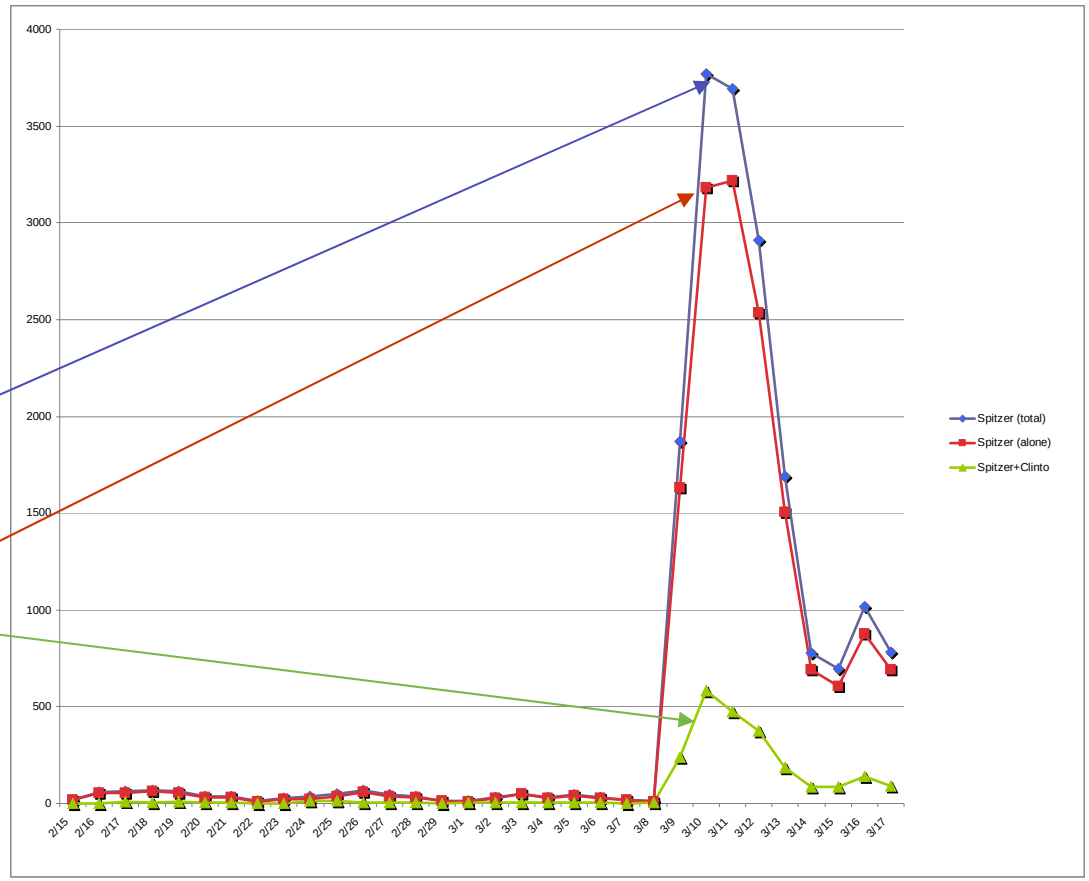
Dashboards for Political Races: Example

Michael Olson:

Frequency of blog posts as a function of date:

Spitzer total
Spitzer & no Clinton
Spitzer and Clinton

Data computed from Spinn3r by permission



My Message: Changing emphasis in CS

1. **Ubiquity of computing and information flow in the sciences, engineering infrastructure and society.**

2. **Education – PhD to K-12 – attention to information flows in the physical and social environment.**

3. **Greater emphasis on interdisciplinary courses, long-term multidisciplinary projects.**

4. **Shift from right/wrong to better/best reasoning**