21CSI®

Unique Tools for Complex Systems®

VISHON:

Vertical Integration of Sensors providing Human-on-the-loop Optimal kNowledge

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13th ICCRTS 2008

Dr. Amber Fischer and Nathan Denny

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21CSI Mission Statement

- Apply intelligent agent-based decision support tools across the spectrum of mission needs for government and commercial customers.
- Bring humans and computers together in collaboration to perform better combined than alone.
- Founded in 1996
- Over 140 employees strong
- Selected in 2005 as an Inc. 500 company for 319% growth
- Offices in HI, WA, CA, NE, MO, IN, RI, VA, CO and soon FL
- Top Secret Facility Clearance

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VISHON Themes

- Contemporary Operations
- Human-on-the-Loop
- Real-time Decision Aids (RtDA)
- Model Compression for RtDA
- Simulation

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Contemporary Operations

- Asymmetric adversaries prefer to operate in urban environments
- Attack and then dissipate under the cover of “urban fog.”
- Kinetic response may endanger civilians
- Friendly forces must act in high confidence

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Human-on-the-Loop

- Semi-autonomous systems are the future!
- "Mission management is the key technology limitation and enabler."*
- Human-on-the-Loop
  - Local decisions made by on-board automation
  - Human operator acts in supervisory role
  - Resource allocation and high-level direction

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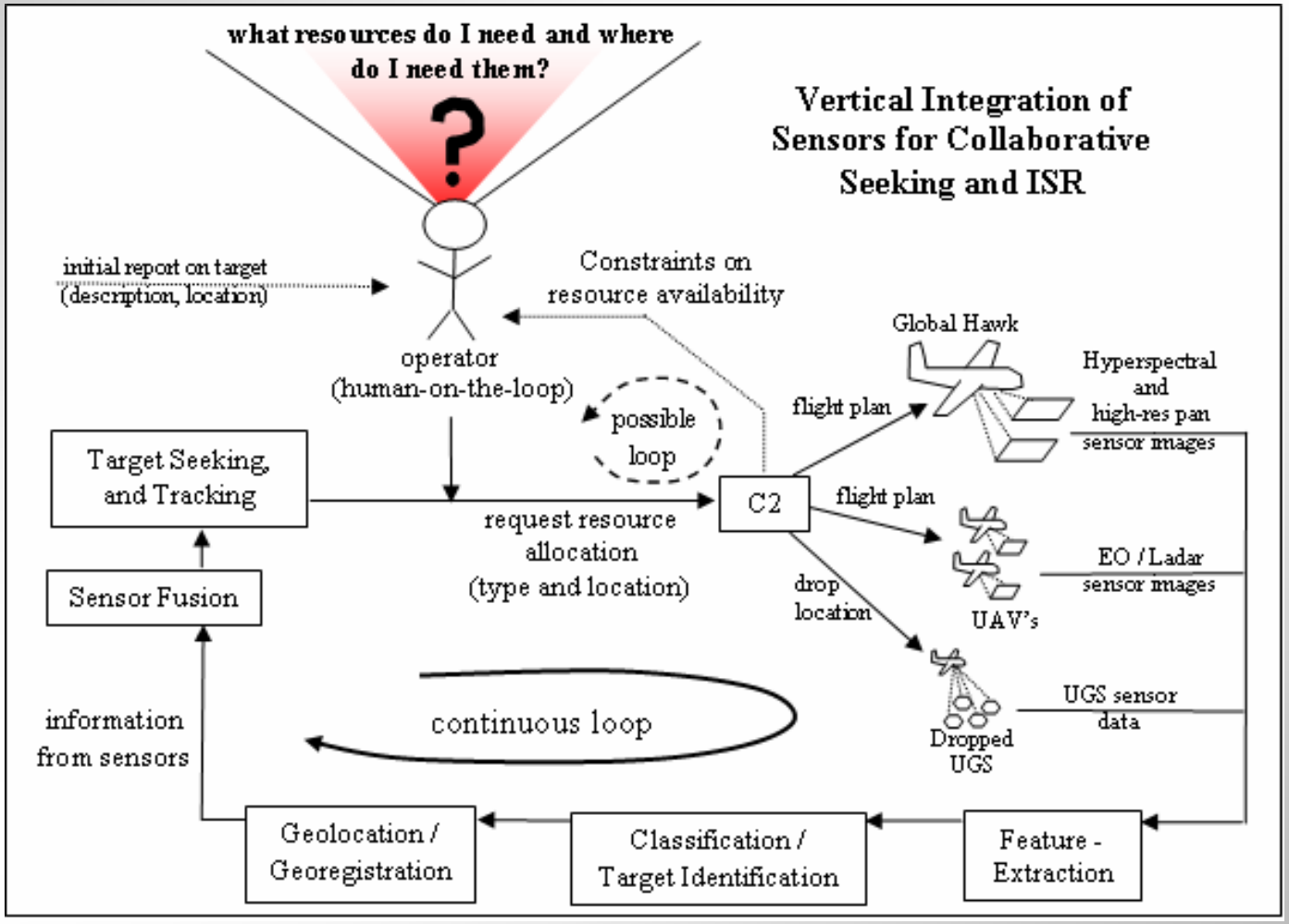
Human-on-the-Loop



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Real-time Decision Aid

- Human-on-the-loop needs different real-time tools than Human-in-the-loop
- Problems of allocation:
  - Evaluate decisions on mission goals
  - Choice of resources
  - Alternative resources (next best)
  - Allocation of resources
- **Every second counts!**

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Model Compression

- Problem too complex → Simulation
- Simulation:
  - high fidelity
  - require little computing
  - require little storage volume
- Pick any two!
- High fidelity simulation unlikely to provide answers to questions in real-time.

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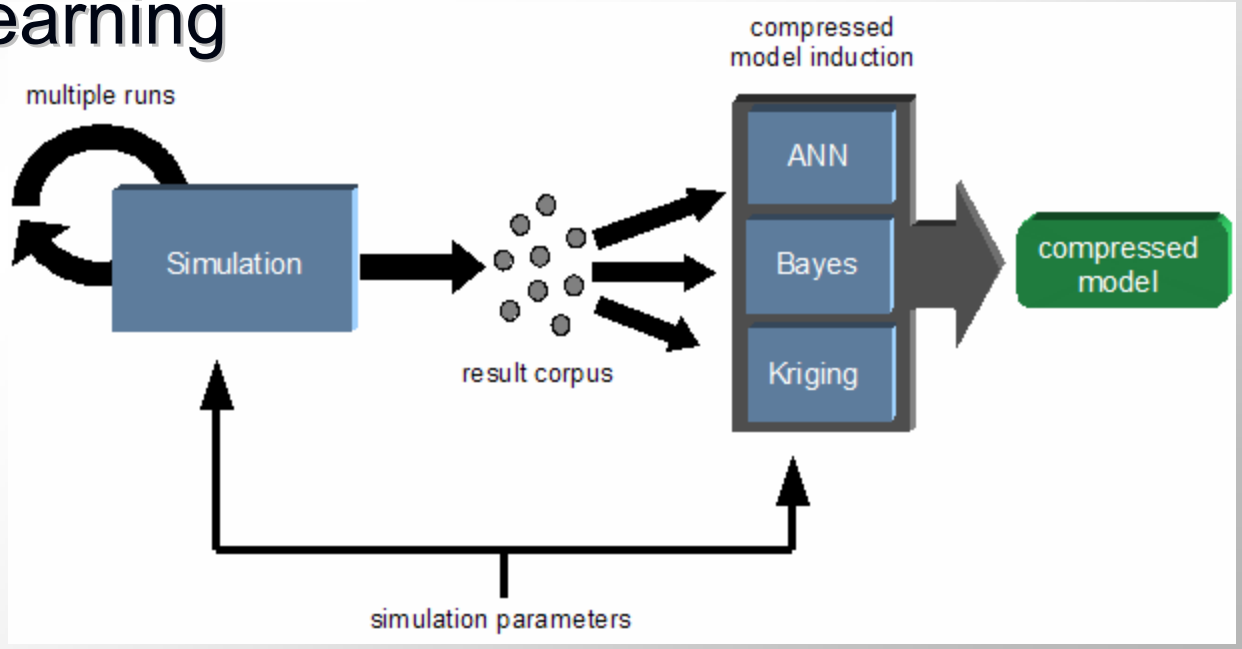
Model Compression

- Construct high-fidelity “macro” simulation
- Capture essential characteristics:
  - Statistics
  - Machine Learning



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Macro and Micro Models

- Macro model
  - High-fidelity
  - Requires substantial computing power
  - Monte Carlo simulation
    - Multiple replications to minimize variance
- Micro model
  - Uses same inputs as macro model
  - Requires much less computing power
  - Direct function evaluation

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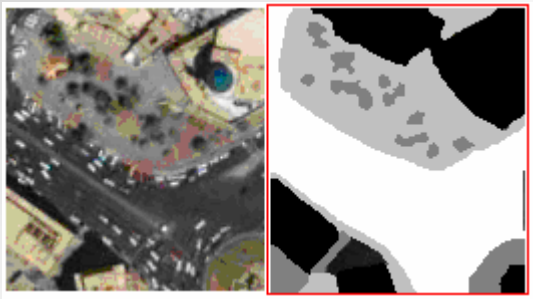
Macro Model: Urban Model

- Road network and traversability



- Traffic flow and driver intent
  - BDI agents
  - Path planning (e.g. A*)

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Macro Model: Target/Sensor

- Objects of interest have discrete set of features
- Mass manufactured vehicles
  - Have many common feature values (color)
  - Enemy likely to employ common model
- Modeled sensors
  - Associated set of visible features
  - Limited range and direction

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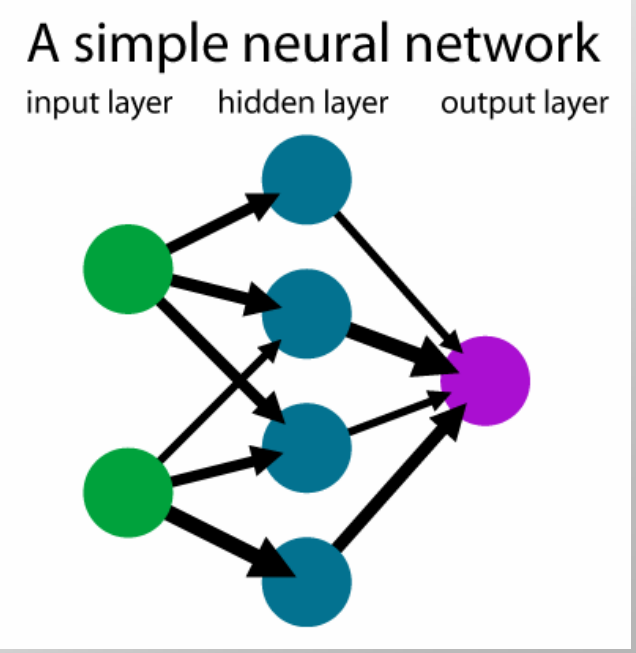
Micro Model

- Perceptron ANN with 10 hidden nodes
- *netlab* toolkit for Matlab
- Trained using corpus generated by macro model
  - Conjugate gradient descent
  - 1,000 training epochs



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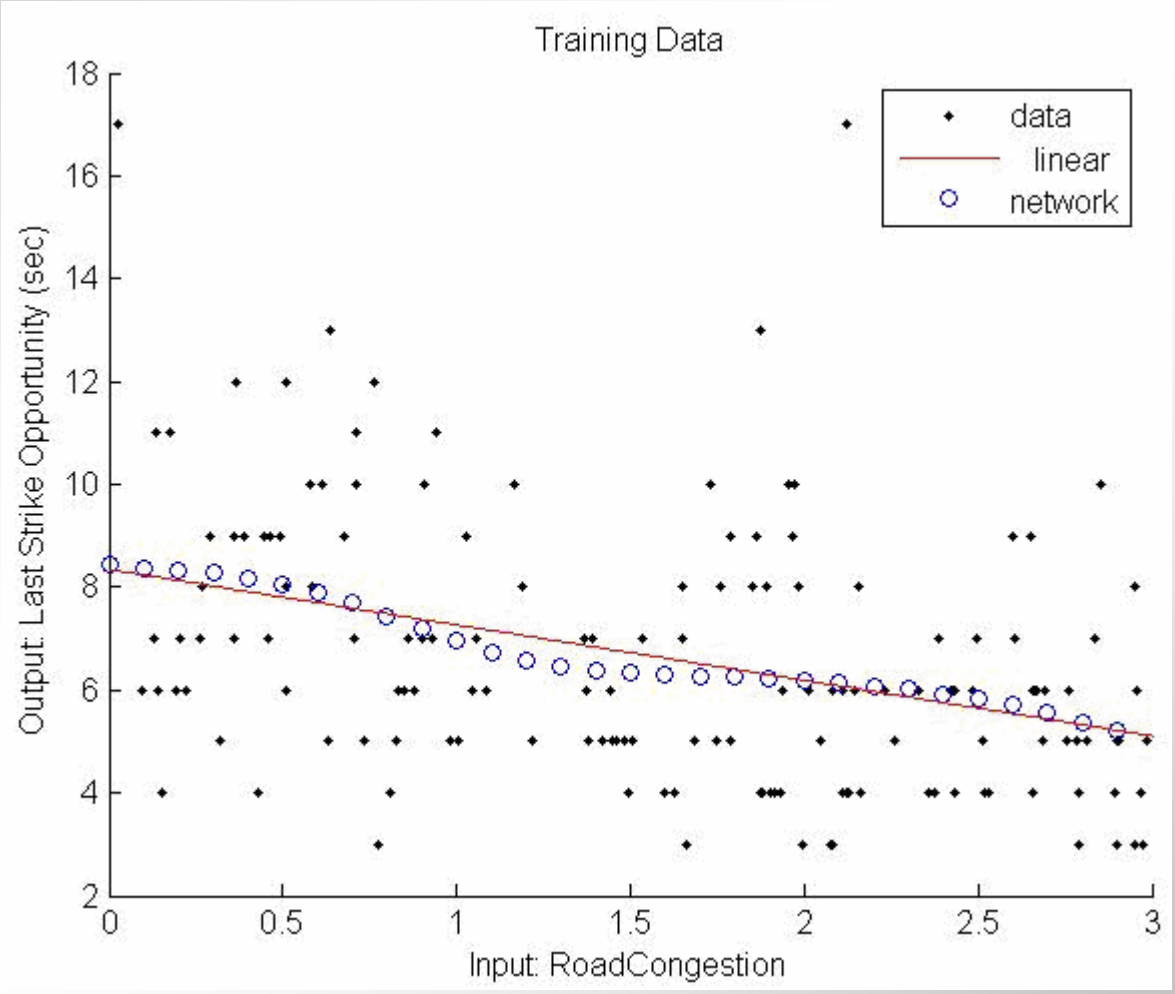
Comparison: ANN Fit



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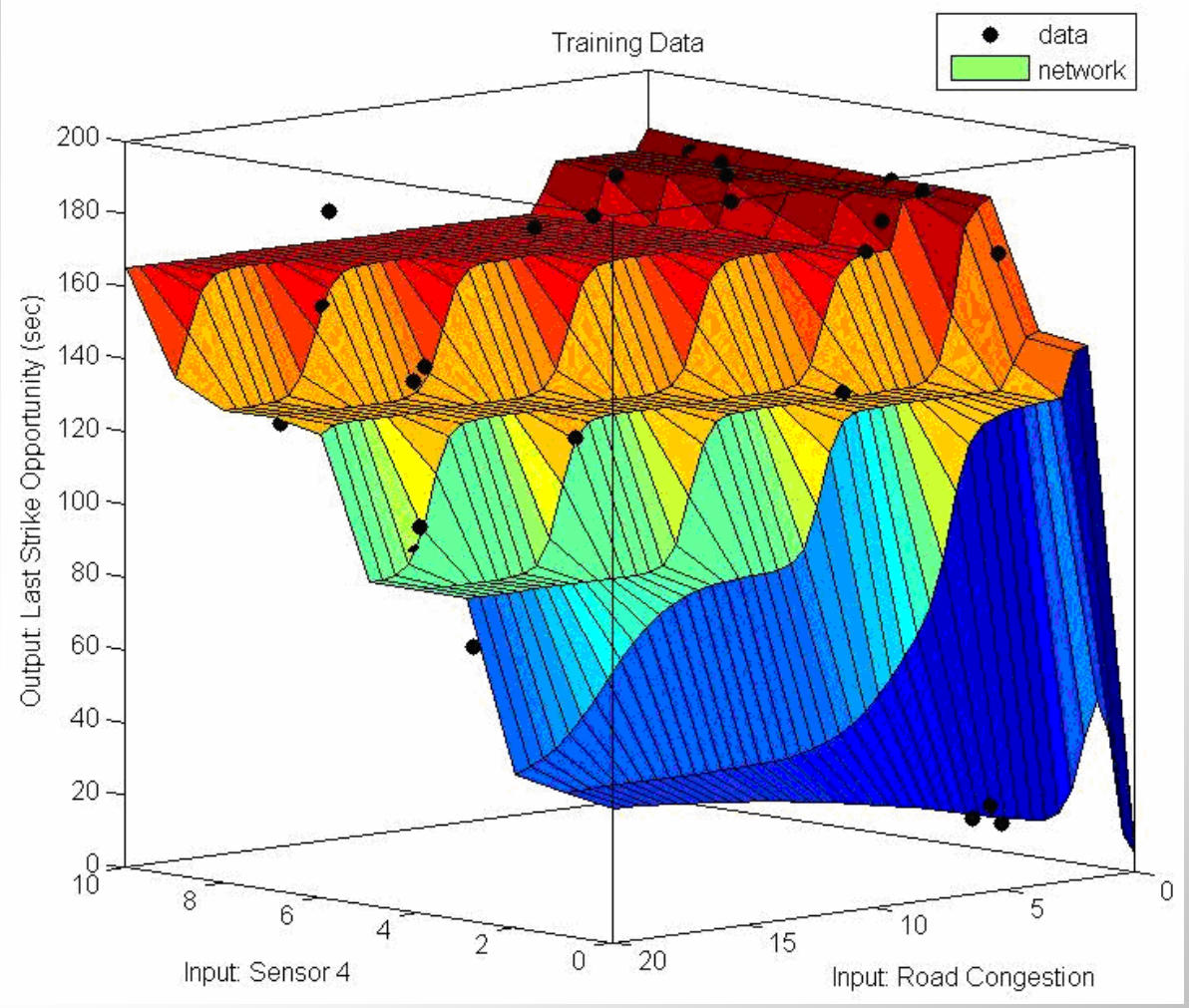
Comparison: ANN Surface



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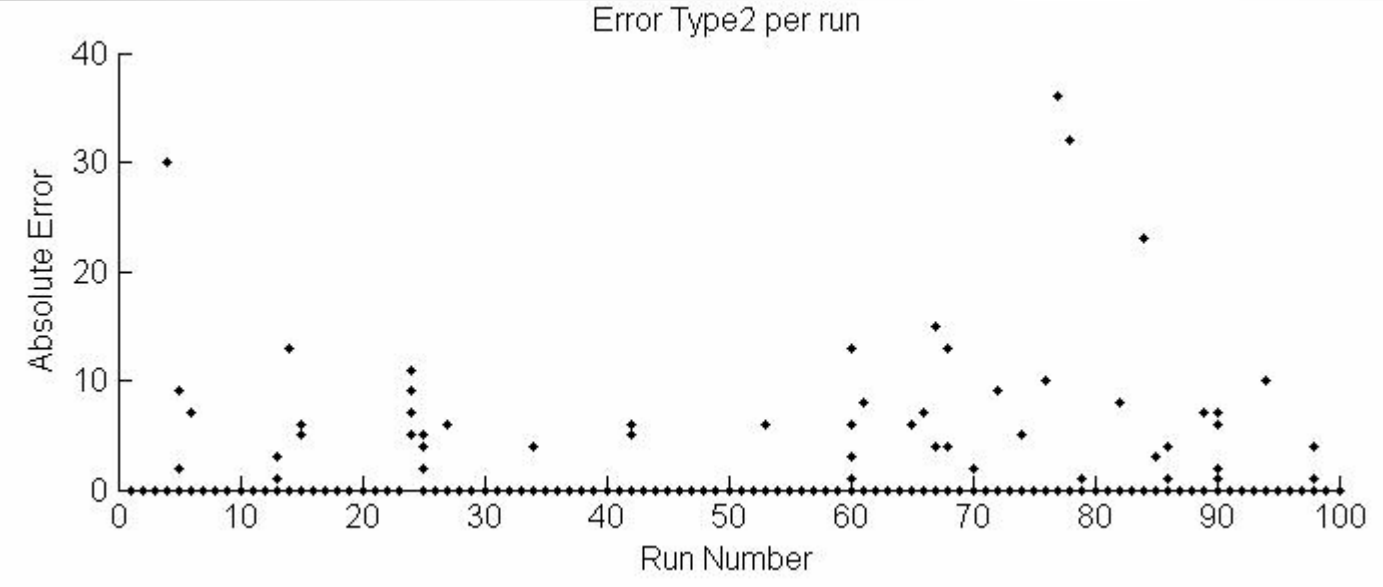
Comparison: Error



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Comparison: Performance

- Using 50 sets of input parameters
- Batch run for macro model* – **30 hours**
- ANN micro model – **0.32 seconds**
- Micro model
  - Fast
  - Requires little storage
- **Micro model suitable for RtDA.**

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Conclusions

- Increasing use of semi-autonomous systems
- Human-on-the-loop supervisory control
- Need for RtDA for Human-on-the-loop
- Complex problems understood through high-fidelity simulation

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Conclusions

- Simulation too expensive for RtDA
- Model Compression
  - Capture salient characteristics of macro model
  - Modest tradeoff in fidelity
  - **LARGE** gain in computability
  - Useful for RtDA applications

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Company Technologies

- Pioneer in agent-based Decision Support Systems (DSS) for time- and mission-critical military applications
- Over 30 decision support tools across the spectrum of missions
- Space-to-mud-to-ocean bottom DSS developed for all DoD branches
- Applications operate in all types of environments and are OS independent
- Patented software technology with extensive, ongoing IR&D
- Agent environment – AEDGE® (Agent Enhanced Decision Guide Environment)

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Unique Tools for Complex Systems®

Nathan Denny

Omaha, NE, USA

Nathan.Denny@21csi.com

402-502-843

www.21CSI.com

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Evidential Reasoning

- Unknowns in an open domain introduce uncertainty that must be modeled by stochastic means
- Evidence is gathered from real world observations gained from sensors.
- Evidence used to add or remove support of competing hypotheses/theories
- Classic Dempster-Shafer belief model is an example of commonly used evidential reasoning.

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Subjective Logic

- "Although including uncertainty in the belief model is a significant step forward, it only goes half the way in realizing the real nature of human beliefs. It is also necessary to take into account that beliefs always are held by individuals and that beliefs for this reason are fundamentally subjective." - *Audun Jøsang*

- When heuristics and rules are solicited from SMEs, the subjectivity of the SME is transferred into the software artifact.
- Subjective Logic (SL) facilitates the transition of SME functions from human experts into software agents.

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Subjective Logic

- SL is an extension to Boolean logic and probability calculus.
- SL operates on opinions which contain…
  - **Subject** – which authority produced the opinion
  - **Object** – a statement produced by the authority
  - **Belief assignment** – (belief, disbelief, uncertainty)
  - **Atomicity** – a measure of coverage of the belief frame

Belief mass assignment constraint	$b_x^A + d_x^A + u_x^A = 1$
Consensus operation	$\omega_x^A \oplus \omega_x^B$
Discount operation	$\omega_B^A \otimes \omega_x^B$

- **Consensus** operation used to "fuse" opinions
- **Discount** operation used to reduce weight of contribution from opinions (e.g. trust and relevance)

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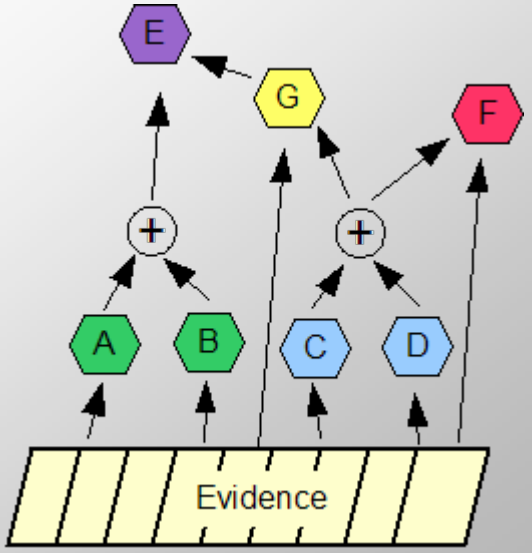
Evidential Reasoning Network

- Evidential Reasoning Network (ERN) is a connectionist approach to composing complex functions from simpler and relatively independent smaller functions.
- Unlike ANNs and BBNs, ERN maintains explicit semantics through the subject and object of propagating opinions.
- ERN is an excellent means for fusing human opinions with software agents to produce a coherent judgment



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