North Carolina A&T State University
A Belief Network Simulation for Sensemaking

Celestine Ntuen, Ph.D.

Distinguished University Professor

Interim Vice Chancellor for Research & Economic Development

Director, Center for Human-Centric Decision Making/ Human-Machine Studies

ntuen@ncat.edu

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North Carolina Agricultural and Technical State University

Explore. Discover. Become.

Presentation Outline

- Preamble
- Sensemaking Definitions
- Why Simulate Sensemaking
- Previous Research
- Belief Net as An Analytical Tool for sensemaking
- Fundamental Assumptions
- Belief Concepts
- Example Problems
- Summary

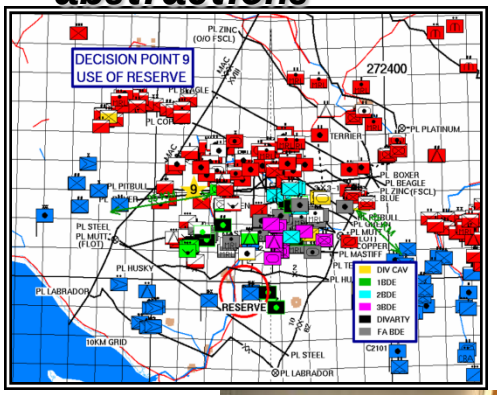
MANY HUMAN ENDEAVORS IN THE BATTLE COMMAND SYSTEMS REQUIRE SENSEMAKING SUPPORT

Collaborative Sensemaking

Individual Situation awareness

Fighting the enemy

Training with abstractions



Team decision making at the TOC

Intelligent gathering

Civil affairs: Negotiation with local tribe leaders

WHAT IS SENSEMAKING ?

Sensemaking: A process, design, or techniques of fusing information in context to derive understanding.

Making Sense: The art or science of making meaning and/ or interpreting information in context for decision making.

How meaning is constructed at both the individual and the group levels (Weick, 1995).

Deriving meaning from fragmentary cues (DARPA'S Information Awareness Project)

It would sure be nice if we had some clear idea what it was we were trying to do first

What is sensemaking?

1. What is relevance in what they see?
2. Are they seeing the same thing?
3. Do they have the same interpretation in context?
4. How does the situation understanding enable action?

IS Sensemaking A Computational Process?

Collection without sense-making, both automated and human,
is both wasteful and falsely reassuring.

Robert David Steele, CEO of OSS.Net,
March 25, 2006

Search is the mind's eye,
But sensemaking is the mind's muscle.

Stuart Card
PARC

WHY USE SIMULATION FOR SENSEMAKING RESEARCH?

(a) cope with complex interaction of multiple behaviors;
(b) be capable of analyzing complex adaptive information;
(c) cope with contingencies under emergence behaviors and events;
(d) recognize opportunities in a spatio-temporal manner;
(e) seek satisficing and plausible (good enough) solutions when confronted with unexpected situations with uncertain and equivocal information;
and (f) represent as much as is feasible the various dimensions of expert knowledge in the domain problems

Problem / Information Types

- ✓"Wicked"—no specific format; e.g., Iraqi conflict, Hurricane Katrina.

- ✓Adaptive/ evolving adversaries and information.
- ✓Complex—multiple, heterogeneous players
- ✓Equivocality—multiple interpretations, meanings and understanding

- ✓Domain specificity.
- ✓Ambiguity/Surprises

- ✓Different types of uncertainty
- ✓Discerning boundary between decision making and sensemaking.

Supporting Views Sensemaking….

1. Is a transcendental cognitive process which allows a complex network of equivocal information to be reduced to a set of plausible actionable knowledge in the context of a domain problem solving task (theory of mind, logical reasoning—mostly abductive).
2. Is the process of transforming a complex set of semantic, tacit, and situational information into a network of ontological representation for the purpose of knowledge discovery (formalism, ontology, knowledge representation).
3. Is a concept map of a sequence of action-reaction-counteraction relationships for constructing courses of action in a complex / chaotic situation (concept maps, cause-effect analysis).
4. Is a method for unmasking latent useful information in a complex information network (data mining, information foraging, knowledge discovery).

Previous Research
Sensemaking Support System (S3) Visualization Software Tool: An Application to Tactical Decision Aiding for Complex Information Management

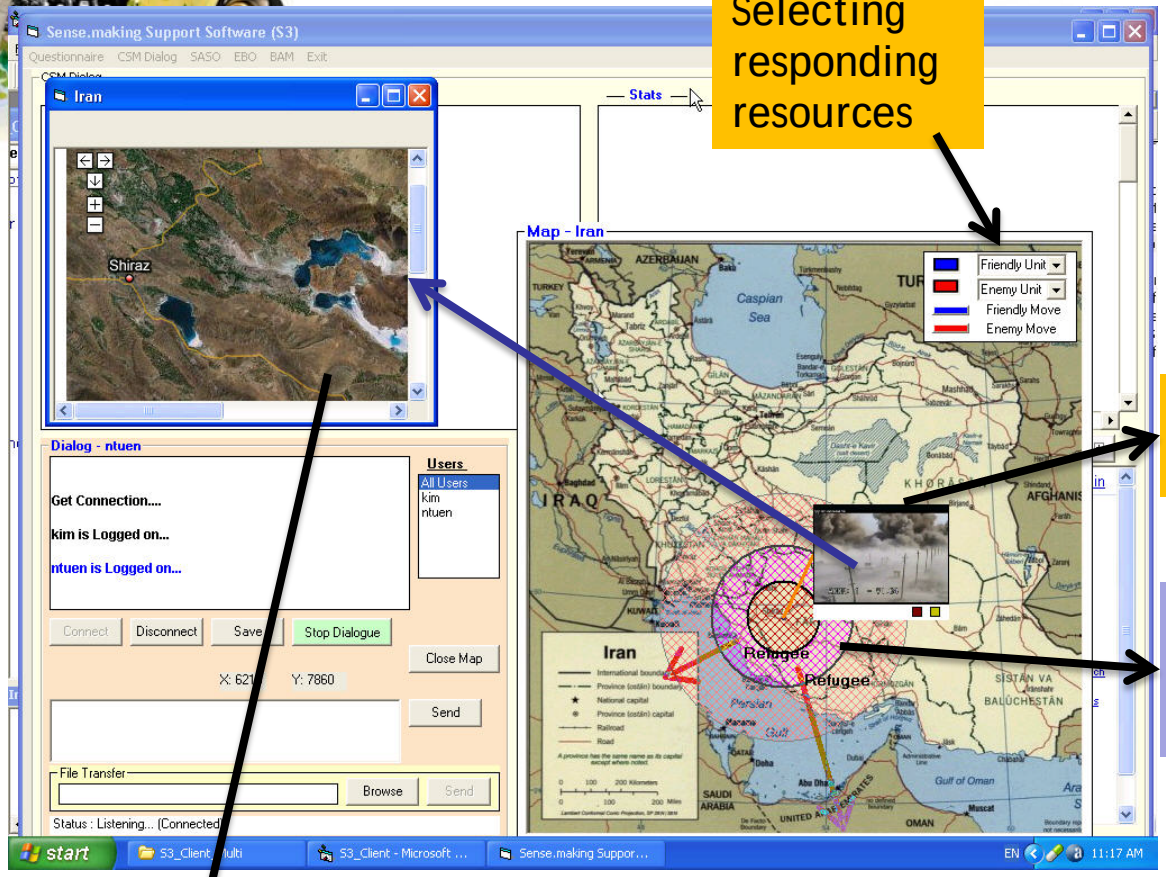
S3 Application in Stability, Security, Transition, and Reconstruction (SSTR) Operation

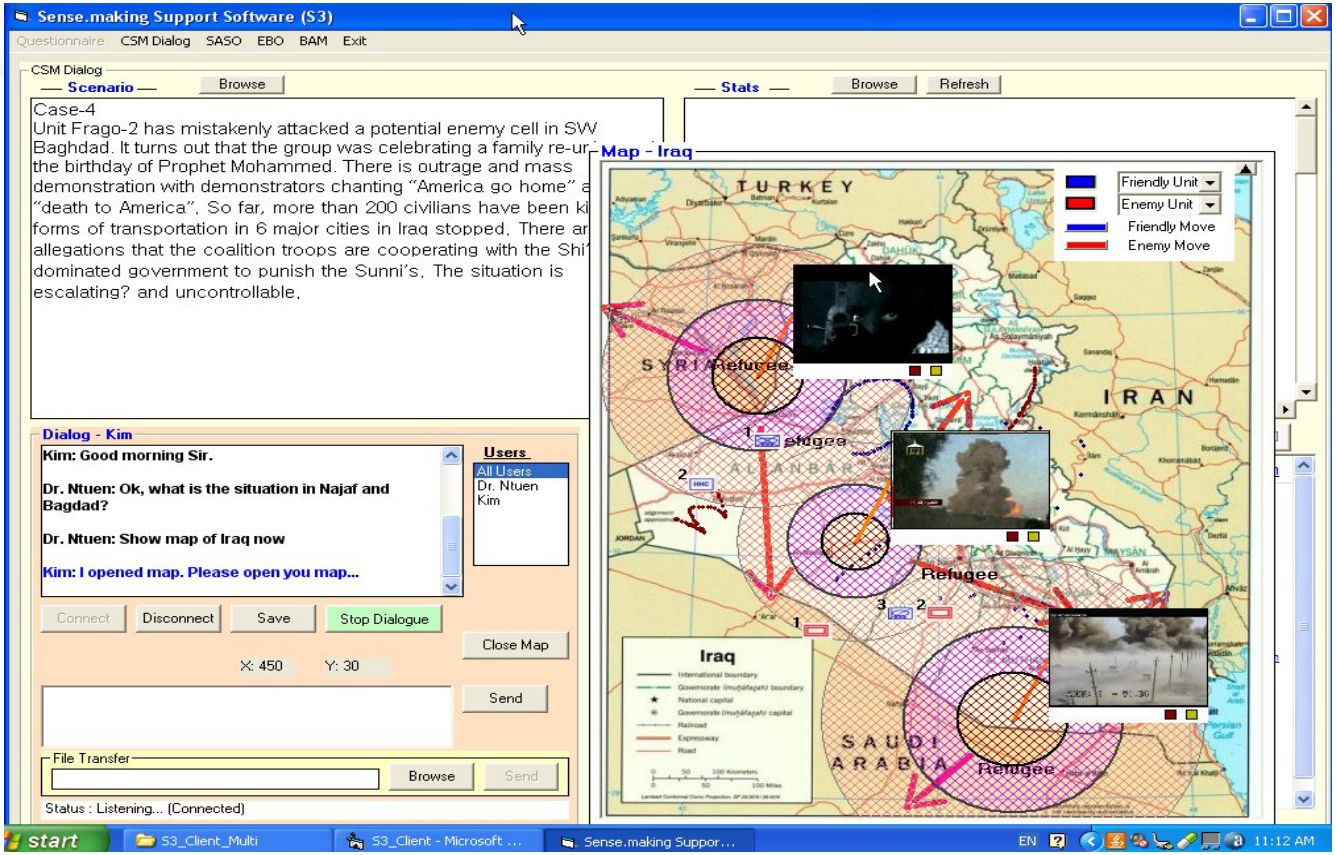
Selecting responding resources

IED explosion

Refugee effect impact

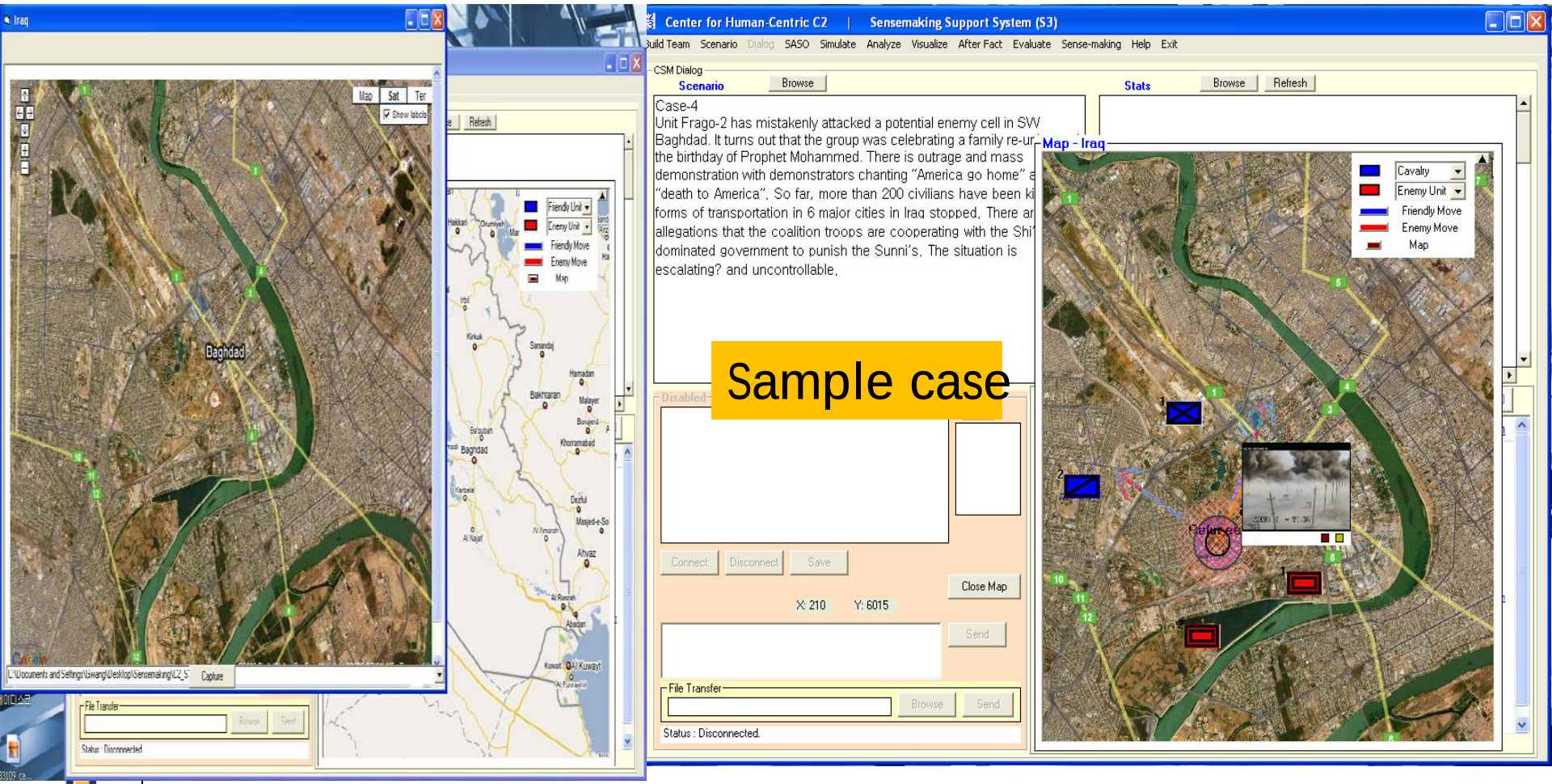
Expanded Information View of the Satellite Image





Sensemaking for Multiple Decision C2 Centers: This research is focused on cognitive and computational modeling of multiple C2 sensemaking processes to support robust, plausible, and adaptive decision making under stress—especially, information fusion from many C2 centers engaged in developing courses of action.

S3 Allows for Terrain Visualization Using Google Earth Map



Belief Net as An Analytical Tool for Sensemaking: Rationale

- Deals with how to reduce uncertainty or ambiguity during decision making processes
- Aggregation of fragmentary information (deriving meaning from fragmentary cues)
- Dynamic re-planning and re-tasking to account for the evolving information in context
- Looking for causality, relationships, and influences. For example, social network, event trees, etc.

Belief Net as An Analytical Tool for Sensemaking: Rationale

Sensemaking for the Intelligence Analysts:

- What happens when new information arrives to the intelligent analyst?
- How does the event network behave over time and space of information life cycle?
- What are influencing factors, relations?
- Do multiple hypotheses converge to reveal significant information about network entities?

Fundamental Assumptions

- The existing analytical models are based on logics and Bayesian trees motivated by Peircean abduction reasoning.
- Markovian models used to handle changes in uncertainties.
- Assumes event nodes with known “belief” values
- The conditional influence between event nodes are rarely known—but can be established by conditional probability function by assuming axioms of probability.
- Needs a better model to account for non-crisp, linguistic description of beliefs.

Belief Concepts

Consider the following case: An expert intelligent analyst says that he has 80% degree of belief that Al-Qaeda network is responsible for kidnapping a foreign journalist in Pakistan. Here, there is only 0% (not 20%) degree of belief that it is not Al-Queda network that is responsible for the kidnapping. The 80% and the 0%, which do not add to 100%, together constitute a "belief function."

Belief Concepts

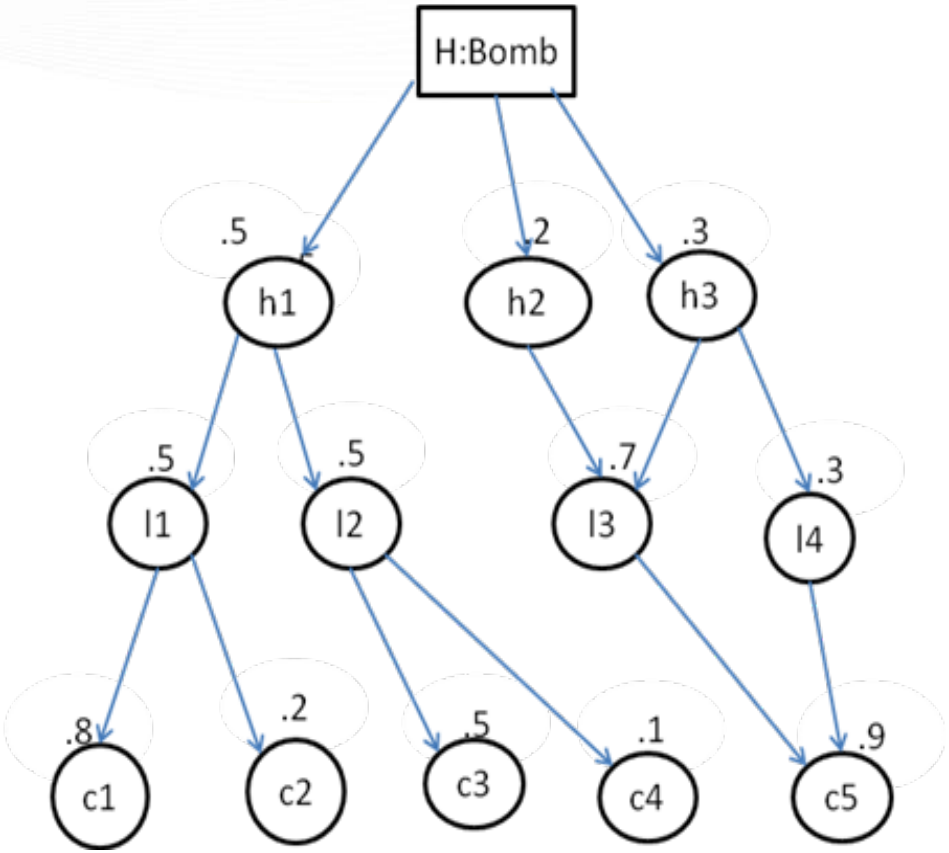
Formally, a belief function is defined as follows: given a set Ω representing a finite set of the world (frame of discernment), the belief function is a mapping from , set of subsets of Ω to [0, 1].

One application of this belief function is on how experts create relations (belief measures) between causation and effects in a domain of diagnostic problem solving, or even notional concept linkages that are implicitly assumed to exist.
In these cases, belief networks are constructed and used to capture cause-effect relations as portrayed by edges of a network. It is usually the case that such belief networks can approximate Bayesian networks which are useful for abductive reasoning—i.e., obtaining approximate inferences about their nature of causes and effects (Pearl, J.(1988). Probabilistic reasoning in intelligent systems: Networks of plausible inference. Morgan Kaufmann Publishers, Inc. Cignoli, R., Esteva, F., Godo, L. & Montagna, F (2002). On a class of left- continuous t-norms. *Fuzzy Sets and Systems,* 131, 283 – 296)

Example Problem

For an illustration (which will be used throughout the remaining part of this paper), assume there is a bomb attack on a football stadium in a major university campus. A group of intelligence analysts is asked to build a sensemaking process of the bomb attack. Assume also that the analysts start the sensemaking process by suggesting three likely suspicious entities for the bomb attack; Let this be H = { , , }. The analysts will take on each assumption and identify major issues, suspected causes, and the likely effects. For the present discussion, let's ignore the effect and concentrate at the issues (I) and causes (C). Figure 1 is used to illustrate an example of the analyst's belief tree about the problem with their associated belief values estimated to be a number between 0 and 1.

Example Problem



Example Problem

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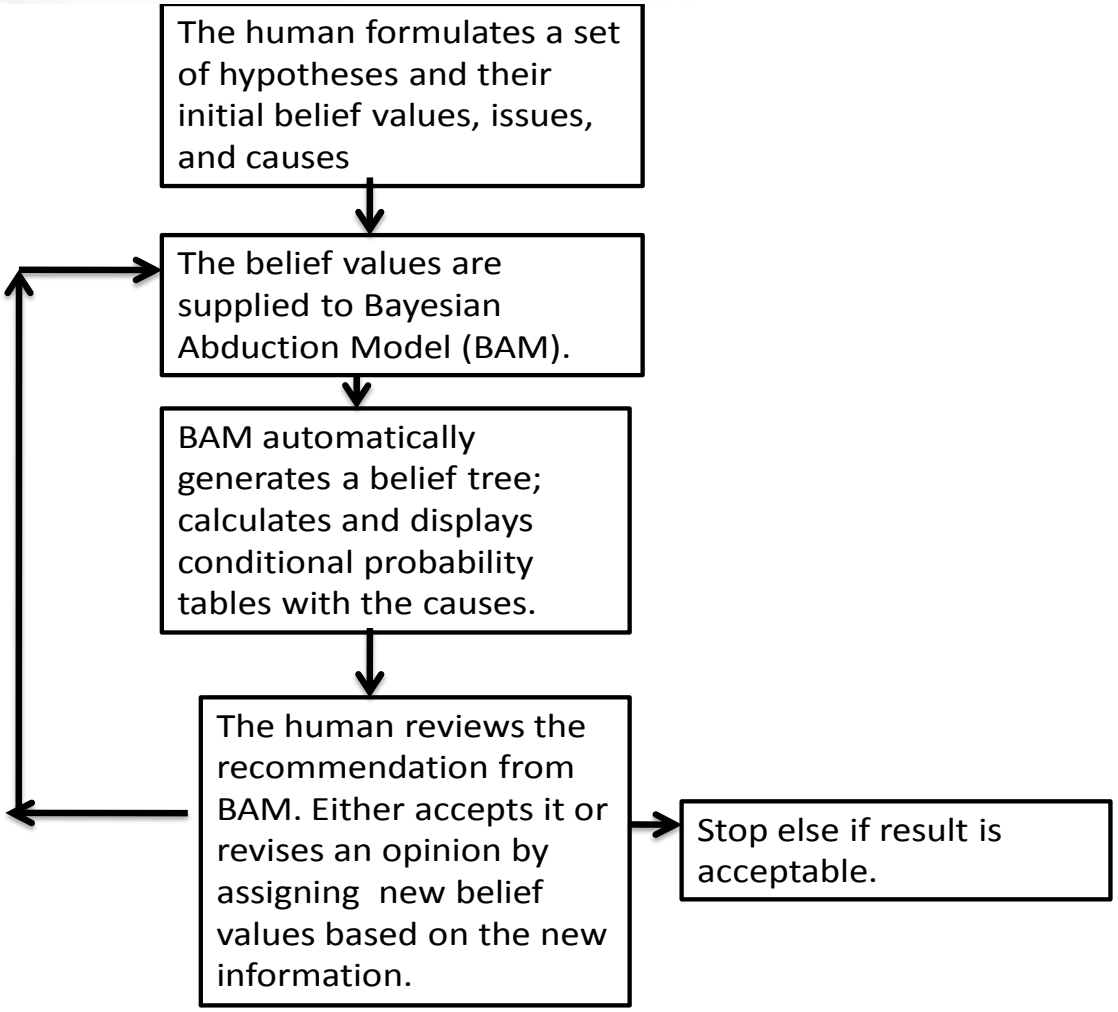
Apparatus

The apparatus is the Bayesian Abduction Model (BAM) component of Sensemaking Support System (S3) software, a personal computer, and 18” TV monitor. S3 can support a team of up to five users or an individual conducting a sensemaking task. BAM-S3 allows the user to conduct multi-hypotheses experiments by interactively refuting, suggesting, and validating the computer-assisted model recommendations. The human-computer interaction steps during the hypotheses experiments is shown in Figure 2.

Example Problem



Example Problem

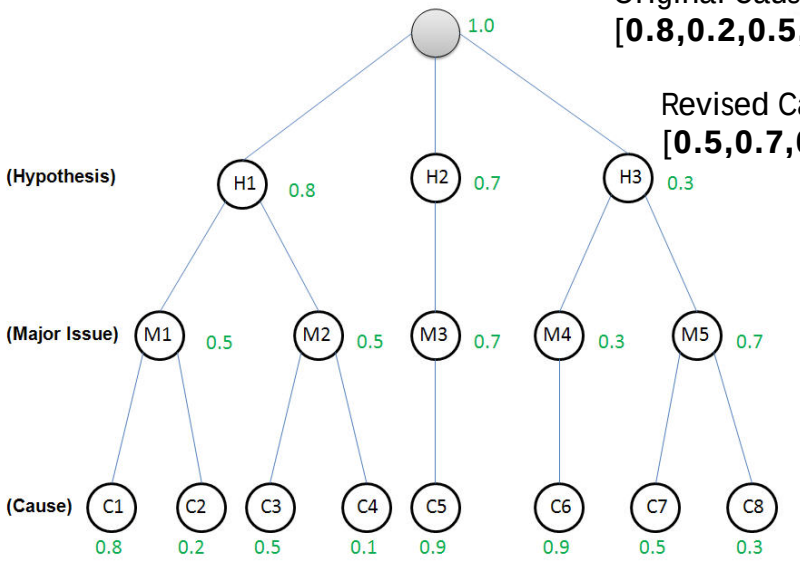
For example, for causal node C_1 related to issue I_1 and hypothesis h_1, the belief that the bomb cause is C_1 is given by $B(\ |c_1) = B(c_1|I_1).B(I_1|h_1)B(h_1|H)$. In general, let n(k), k= 1, 2,…, K; K is the number of hypotheses (in the above example, K = 3); for each hypothesis node, count the number of vertices (m) from each cause node backward to the H node (including H node itself). This backward folding yields the general product equation:

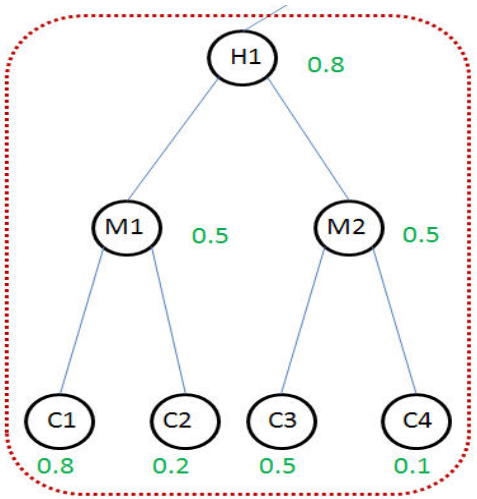
$B(v_i|H) = B(H|v_m) \left[\prod_{i=1}^{m-1} B(v_i \mid v_{i+1})\right]$;where, m $\leq$ n(k), v_i is the node, i $\leq$ m

Bayesian Result = [**0.31920, 0.07950, 0.19875, 0.03975, 0.44049, 0.08055, 0.10455, 0.06273**]

Original Cause = [**0.8,0.2,0.5,0.1,0.9,0.9,0.5,0.3**]

Revised Cause = [**0.5,0.7,0.5,0.4,0.9,0.6,0.5,0.8**]





- H is likely caused by C_5 : **28.81 %**
- H is likely caused by C_2 : **15.48 %**

Hypothesis H_1 :

H_1 is true with probability of **44.44 %**

Causal Effects :

[0.1452(C_1), 0.1607(C_2), 0.1313(C_3), 0.0958(C_4)]

Summary

1. Sensemaking, unlike decision making, is not well grounded on analytical rigor.
2. Challenge: To use expert belief data on a probabilistic belief network requires novel techniques for conditional probabilities. We use fuzzy residuum techniques to achieve this—very promising results.
3. Plan to incorporate Klein's Data Frame Model (DFM) into the simulation suite. A finite state automoton will do the trick (Developing FAS/DFM Simulation Engine for Sensemaking).
4. Plan to incorporate and measure effects of cognitive biases.
5. The model allows for:
    1. Testing multiple hypotheses in teams
    2. Testing multiple hypotheses by individuals
    3. Calculation of believability index (team or individual)

Questions?