Bringing Cognitive Engineering to the Information Fusion Problem: Creating Systems that Understand Situations

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Goals for Computer Models of SA

Replace human decision making

Augment human decision making
  – Must be capable of sharing its “SA”
What do we mean by Computer SA?

• Do computers have “awareness”?

SA = Model of the current situation
• Model of the current situation
  – Perception of elements
  – Comprehension of meaning
  – Projection of future status
Specific Requirements Can be Defined For a Given Position

Where are we? Where are they? What is the weather? What is the terrain?

Highest priority threat Deviation from plan Combat readiness Level of risk to assets Priority of information Areas needing coverage

Predicted enemy COAs Predicted friendly COAs Predicted impact of friendly actions on enemy COAs Predicted location of weapons systems Predicted effects of weather Predicted effects of terrain Predicted enemy objectives

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Current State of the Art Human-Centered Fusion

Know the Situation. Know the Solution.

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Challenges for SA

• Lots of Data
  – Some relevant/some not
  – Varying levels of reliability

• Lots of Noise
  – Transmission issues
  – Conflicting data

• Limited Bandwidth
• Limited Processors
Learning from Human Situation Awareness

**SITUATION AWARENESS**

- Perception of Elements In Current Situation
- Comprehension Of Current Situation
- Projection Of Future Status

**Level 1**
- Abilities
- Experience
- Training

**Level 2**
- Goals & Objectives
- Preconceptions (Expectations)

**Level 3**
- System Capability
- Interface Design
- Stress & Workload
- Complexity
- Automation

**Task/System Factors**

**Individual Factors**

*Endsley, 1988, 1995*
Mechanisms of SA

Perception → Comprehension → Projection

Directs Attention

Mental Model

Provides Comprehension & Projection

SA Guides Selection of Active Goal

Active Goal Selects Model

Goals
What Allows People to Achieve High Levels of SA?

- **Schema**
  - Prototypical & Expected
    - Objects
    - Scenes
    - Order of Events

- **Critical Cues**

- **Mental Model**
  - What information is attended to
  - How information is interpreted and integrated
  - What projections are made

- **Perception**
- **Comprehension**
- **Projection**

- **Situation Model (SA)**

- **External Cues**
Evolution of Mental (Computer) Models

Feedback Learning

Model A

- Prediction of world state
- Comparison to actual world state

Model A’

- Refinement of Model
  - better categorization
  - more categories
  - better transition functions

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Situation Model must Capture Uncertainty (Confidence Level)

SITUATION AWARENESS

State of the Environment

Perception of Elements in Current Situation Level 1

Comprehension of Current Situation Level 2

Projection of Future Status Level 3

Decision

- Missing data
- Reliability of data
- Conflicting data
- Timeliness of data
- Ambiguous/noisy data

- Mapping of data to relevant categories/schema
- Future inherently uncertain
- Probability that selected course of action will result in desired outcome

As fusion level goes up, so does need to support confidence assessments

Endsley, Bolte & Jones, 2003

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Information Confidence & Uncertainty

SA and Confidence Level in that SA will Effect Willingness to Act & Outcome

Situation Awareness

Confidence Level

High

Good Outcome

Bad Outcome

Low

Do Nothing (Ineffectual)

Okay Outcome (Delay)

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Christ et. al. (1994) and Endsley and Jones (1997)
Levels vs Stages

Perception, Comprehension & Projection are not necessarily linear stages

Act: Directed Search

Perception

Comprehension

Projection

Decide: Need more info

Levels 2 & 3
Can be used
To drive the search
For Level 1 info

Default values from the mental model can provide reasonable values, even when no level 1 info has been perceived on an element

Confidence in SA
Meaning is not Determinate
Depends on Goals

Workplace

Sightseeing

Obstacle

Terrorist Target

Meaning is in the eye of the beholder
Situation Awareness - Driven by Alternating Data Driven and Goal Driven Processing

Goal Driven Processing (Top-down)
- Goals Determine Selection of Model for Interpreting Information
- Goals Determine Development of Level 2 SA
- Goals Direct Attention

Data Driven Processing (Bottom-up)
- Salient Cues “Catch” Attention
- Cues Interpreted
- Options Generated/Evaluated
- Option Selected
- Appropriate Actions taken

Goals are key organizing feature for cognitive work

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Transitioning Goals

Main Goal

Subgoal 1
- Subgoal 1.1
- Subgoal 1.2

Subgoal 2
- Subgoal 2.1
- Subgoal 2.2
- Subgoal 2.3

Activation criteria

Dynamic Goal Prioritization
Goals & Mental Models in SA

MENTAL MODEL

(IDEAL STATE)
GOALS

(PROJECTED STATE)
PLANS

(OUTCOME)
SCRIPTS

(ACTIONS)

(SITUATION MODEL)
SITUATION AWARENESS

ENVIRONMENT
Information from the world is filtered through the users senses to form SA. SA influences goal activation, active goals drive mental model selection, and mental models direct attention to sensory information.
Approaches to Fusion

Bottom up

Elements (Level 1)

Comprehension (Level 2)

Projection (Level 3)

Can’t achieve higher levels of fusion Without understanding goals & Decisions of users
Approaches to Fusion

Top Down

Goals

Decisions

Projection (Level 3)

Comprehension (Level 2)

Elements (Level 1)
Computer Models of SA Will Need:

• An internal “Mental Model” of the system/environment
  – Defines “Relevant”
  – Provides Dynamic Information Prioritization
  – Provides Mechanism for Dynamic Integration of Data Creating Meaning
    • Comprehension required
    • Projections required
  – Active Learning and Model Refinement
  – Links to Schema and Scripts for Prototypical Situations

• Goals
  – Pre-requisite to Relevance and Meaning
  – There are frequently Multiple Goals which Vary in Priority
  – Need a Mechanism for Goal Prioritization
    • Critical Cues to Trigger Goal Priorities
Towards Methods for Creating Usable Computer Models of SA

Specific Requirements Can be Defined For a Given Position

Where are we? Where are they? What is the weather? What is the terrain?

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Low Level Data Fusion

SA Theory

Level 0 Source Preprocessing
Level 1 Object Refinement
Level 2 Situation Refinement
Level 2 Comprehension

High Level Data Fusion

Level 2 and 3 Comprehension & Projection

Level 3 Impact Assessment
Level 4 Process Refinement
Level 5 Cognitive Refinement

Current State of the Art

Human-Centered Fusion

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Goal Directed Task Analysis

1.0 Major Goal

1.1 Subgoal

Decisions

SA Requirements:
Level 3 - Projection
Level 2 - Comprehension
Level 1 - Perception

1.2 Subgoal

Decisions

SA Requirements:
Level 3 - Projection
Level 2 - Comprehension
Level 1 - Perception

1.3 Subgoal

Decisions

SA Requirements:
Level 3 - Projection
Level 2 - Comprehension
Level 1 - Perception

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Example – Logistics Officer

Maintain Unit Readiness –
Keep units 100% supplied

1.0 Project future supply needs of units
2.0 Update/adjust supply plan
3.0 Coordinate supply scheme for units
   3.1 Recommend Allocation of Land
   3.2 Maximize efficiency of resource allocation
   3.3 Maintain Brigade Assets (equipment) to Support Unit Readiness
   3.4 Maintain Budget to Support Unit Readiness
4.0 Coordinate Transportation
   4.1 Transport Supplies / Personnel Safely and Efficiently
   4.2 Establish Transportation Timing
Example - Military Logistics

Subgoal

Establish
Re-Supply Timing

Decision

What is the best timing for re-supply?

SA Requirements

Projection

Comprehension

Data

- Projected replenishment timing / locations
  - Impact of delayed replenishment
  - How long units can go without replenishment
  - Impact of supply shortages on units combat readiness
  - Effect on support platoon supply status
- Effect of battle rhythm on replenishment timing / location
- Unexpected pauses in the battle
- Mission phase
- Replenishment options
  - Time available for replenishment
  - Time required to accomplish replenishment
  - Distance
  - Items being replenished
- Mobility requirements
  - Type
  - Fuel requirements
  - Operation base
- Logistics supplied organically by each unit
- Priority of support
- Mission phase
- Mission timing
- Unit role in mission
- Accessibility of replenishment area
  - Road trafficability
  - Capability of supply vehicles
  - Capability of vehicles being supplied
  - Basic loads
  - Landing zones
- Impact of force protection required
- Projected timing for launch of replenishment operations
  - Impact of pre-time
    - Time to prepare transportation vehicles
      - Maintenance
      - Fuel
    - Time when items available to load
    - Time to load supplies on transportation vehicles
    - Personnel available for preparing transportation vehicles
- Impact of early/late departure to replenishment area
  - On safety of route
  - On safety / readiness of supply area
  - On road availability
  - On unit availability to replenish
Create model through learning approach based on SAGAT data

Actual World → Perceived World → Decision

SAGAT Measurement → Learning Procedure → Fusion Model

Series of Snapshots Of the Situation Model

Collected Across a Wide Variety of Situations, these Snapshots may be Reconstructed to Develop A Representation of the Mental Model

Tactical Situation Display

490 Data Sets (2-12 targets)
10 Fighter Pilots
Decision as what would do

Model performance indistinguishable from that of pilots

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Know the Situation. Know the Solution.
Fuzzy Cognitive Modeling of SA

- **SA-FCM cognitive model**
  - **Fuzzy logical model of SA**
    - Does not require apriori data
  - **Naturalistic decision model**
    - Modeled based upon information needs and the relationships of information to decisions and goals

- **Rationale**
  - Avoids rules or artificial parameters
  - Reveals steps of computing processes
  - Can handle information that is unknown or incomplete
  - Integrates real time information
SA-FCM for Infantry operations

- Created SA-FCM for understanding Platoon Leader SA
- Passed Turing test in simulated mission in VBS2
Creating the Human-Computer Team

• Must Build Shared SA Across the Human and the Computer
  – To avoid being on “different pages”
  – Achieve effective collaboration
  – Optimal decision making
Mental Models

Goals

SA

Displays Environment

Computer Models

Goals

SA

Displays Environment

Sensors Inputs
Shared SA Requirements

- **Data**
  - system
  - environment
  - other team members

- **Comprehension**
  - status relevant to own goals/requirements
  - status relevant to other’s goals/requirements
  - impact of own actions/changes on others
  - impact of other’s actions on self & mission

- **Projection**
  - actions of team members

Shared SA Needs
From Shared Goals

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Know the Situation. Know the Solution.
Summary

- Computer models of SA are a major goal for intelligent systems
- Foundation is laid for attributes and mechanisms needed for robust computer situation models
- Cognitive engineering tools and methods can be leveraged to make significant advances in the current state of fusion
- Resultant “intelligent systems” need to support shared SA goals of the human/system team or they will not be well utilized