

The Role of Meta-Information in C2 Decision-Support Systems

Command and Control Research and Technology Symposium:
Cognitive and Social Domain Issues – Track 6

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Overview

- General Motivation and Goals
- Approach and Methods
- Description of Domains
- Results of Analysis
- Implications and Conclusions



General Motivation

- Interest in uncertainty w.r.t. system design & development
 - In Artificial Intelligence community
 - Probabilistic reasoning techniques
 - Representational formalisms
 - In Cognitive Engineering community
 - In decision-making (e.g., trust and uncertainty)
 - For visualization and interface design
 - In Military environments
 - Asymmetric warfare
 - Increase in HUMINT
 - Increase in information in NCW

- Anecdotes across many domains...



General Motivation

- **“Uncertainty” is not enough**
- Information may be qualified in other ways
 - Importance, Quality, Impact, Pertinence
 - Recency, Staleness, Timeliness
 - Ambiguity, Accuracy, Precision
 - Pedigree, Confidence, Reliability
 - ...
- **“Meta-Information”**
 - ... is a concept/term that captures information qualifers more generally



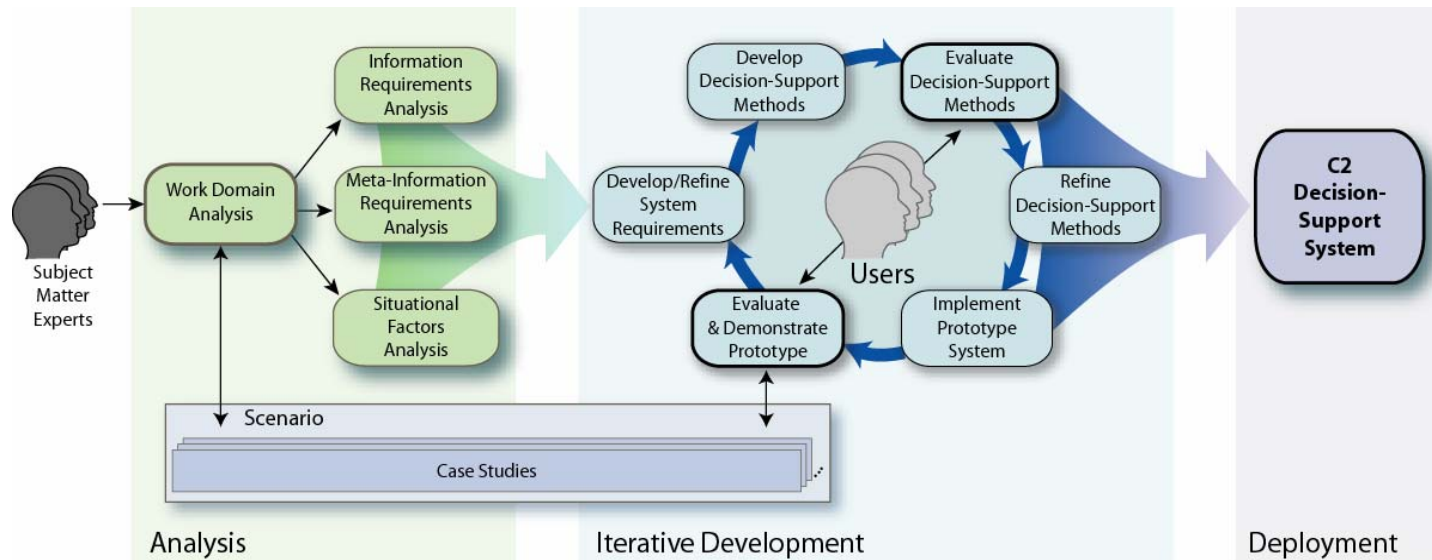
Goals

- Establish that meta-information must be considered in C2 system design by summarizing analyses across C2 domains
- Provide guidelines to support the design of C2 decision-support systems w.r.t. meta-information
 - Displays and user interfaces
 - Computational methods
- Encourage design processes that aid in understanding meta-information requirements
 - Because of task and context dependence of meta-information



Analysis Method

- o Performed analysis as part of Cognitive Systems Engineering methodology



Analysis Approach

- Constructed hypothetical scenarios to explore context
- Conducted structured interviews with domain experts
- Performed analysis to:
 - Identify key sources of complexity and types of decisions
 - Uncover sources and types of:
 - Data
 - Meta-data
 - Information
 - Meta-information
 - Identify required information and meta-information
 - Discover situational influences on requirements



C2 and C2-Related Domains Analyzed

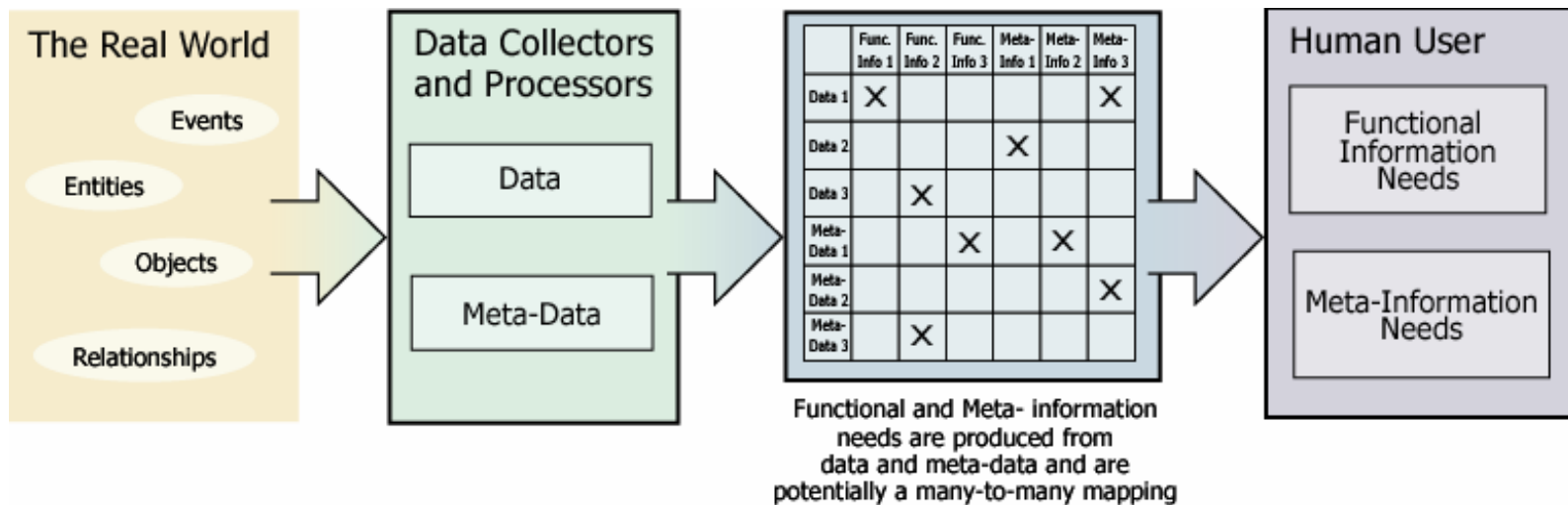
- Intelligence operations
- Small-unit tactical maneuvers
- Sensor management
- Weather impact assessment
- Natural disaster management

(Our thanks to the many domain experts we interviewed and observed!)



Results of Analysis

- Identified information needs
- Identified meta-information needs
- Defined meta-information concepts



Working Definitions

- **Data**: output (processed or unprocessed) from a human or machine system – e.g.,
 - Acoustic sensor X reports 34 Db
 - Joe says it is raining
- **Information**: an input to a directed decision-making process – e.g.,
 - A storm is coming, thus I will not launch the weather balloon until tomorrow
- **Meta-Data**: characteristics or qualifiers of data – e.g.,
 - Temperature sensor Y has an error of +/- 0.1 deg F
- **Meta-Information**: characteristics or qualifiers of information, affecting a human's:
 - Information processing
 - Situational awareness
 - Decision-making
 - E.g., There is a 60% chance the fire is located at {x,y} therefore I will confirm its location before sending fire trucks



Definitions, cont'd

- Is “meta-information” just “information”? No.
 - It *qualifies* information
 - It may be reasoned about differently
 - E.g., qualifiers may be ignored under high time demands
 - It tends not to be regularly captured or represented in many human-machine systems where it is needed
- How we might define data, meta-data, information, and meta-information depends on
 - The decision-making task
 - The context or situation



Meta-Information Definitions across Tasks

	Sensor Management	Tactical Decision-Making
Data	Sensor X reports 42.2 dB Sensor Y reports 32.1° F	Sensor X reports 42.2 dB Sensor Y reports 32.1° F
Meta-Data	Sensor X error is $\pm .4$ dB Sensor Y reports at 5 Hz	Sensor X error is $\pm .4$ dB Sensor Y reports at 5 Hz
Information	Location of sensors Sensor types "Health" of sensors	Location of targets Type of targets Number of targets
Meta-Information	Accuracy of sensor status Recency of sensor status	"Health" of sensors Coverage of sensors Accuracy of target information Recency of target information



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More Results

- Analyses showed wide range of types of meta-information
- The following provide examples of meta-information types we encountered...



Types of Meta-Information Discovered

- Characteristics of the source of the information
 - Type of data the source can produce
 - Type of processing used
 - Range of data generated
 - Baseline error rates
 - Frequency of reporting
 - Ability to report on its status and characteristics of that report
 - Inherent biases
 - Past performance, history
 - Directly observing or deriving information



Types of Meta-Information Discovered

- Characteristics of the source varying with other information
 - Time
 - Location in environment (e.g., terrain, weather)
 - Types of intermediate processing
 - Content of report
 - Information context
- Uncertainty
 - Spatial uncertainties
 - Temporal uncertainties
 - Uncertainties about uncertainty reporting
 - Likelihood
 - Probability
 - Confidence
 - Accuracy
 - Precision



Types of Meta-Information Discovered

- Ambiguity
 - Specificity or resolution of information
 - Level of abstraction of information
- Information context (i.e., relationship to other information)
 - Degree of confirming or disconfirming information
 - Paucity of information
 - Frequency of reporting of information
 - Missing or degraded information qualifiers
 - Information-to-noise ratio
 - History
- Reliability of source
 - W.r.t. source characteristics
 - W.r.t. information context



Types of Meta-Information Discovered

- Credibility of content from source
 - W.r.t. reliability
 - W.r.t. type of content
 - W.r.t. type of source
 - W.r.t. information context
- Relevance or pertinence
 - W.r.t. specific mission goals
 - W.r.t. actual/perceived information needs
 - W.r.t. broader operational context
 - W.r.t. current hypotheses about the situation
- Temporal qualifiers
 - Staleness
 - Recency
 - Certainty about time of reporting
 - Latency
 - Lag
 - Absence of expected information



Meta-Information and C2 Decision-Making

- Uncovered three complexities related to decision-making and meta-information
 - Failure to recognize relevant meta-information
 - Failure to process meta-information appropriately
 - Failure to properly utilize meta-information
- These complexities apply to both
 - Human decision-making
 - Machine reasoning



Implications & Future Work: Computational System Design

- Need to represent meta-information needs in data structures, computational processes
- Need to calculate meta-information from data and meta-data
- Need to aggregate meta-information
- Need to process types of meta-information simultaneously
- Need to minimize impact of additional computation

- Future work:
 - What representational formalisms are amenable to handling multiple types of qualifiers?
 - What computational processes support reasoning over qualified information?
 - To what extent can existing methods be adapted to support meta-information needs?
 - ...



Implications & Future Work: Display and Interface Design

- Need to communicate meta-information in a situation- and task- relevant manner
 - What visualization methods work for what types of meta-information?
 - How does the information type and its display method interact with the meta-information visualization?
- Need to avoid overloading the user with the presentation of meta-information
 - How and when does the presentation of meta-information cause overload?
 - What user interface mechanisms could aid in avoiding overload?
- Need to aid reasoning about and with meta-information
 - What displays/UIs facilitate a user's ability to understand and exploit meta-information?
 - How can users be trained to recognize and use meta-information?



Conclusions

- We must go beyond thinking only about uncertainty
 - Information may be qualified in many ways
- Meta-information needs should be reflected in C2 decision support systems:
 - As part of underlying computational methods
 - As part of displays and interfaces
 - With awareness of task and situation dependencies
- Additional work remains to be done...



Questions?

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