Decision Assurance:
Enhancing Decision Maker Perception with Feed-Forward Control

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ABSTRACT

Information systems (IS) provide decision makers with indirect observations of the environment, but such information is often striped of direct observation contextual cues such as information quality criteria. Feed-forward control (FFC) utilizes sensors governed by information quality criteria like accuracy, relevance, timeliness, usability, completeness, brevity, and security to monitor IS data flows for disturbances to human and/or machine decision maker task specific information quality criteria requirements. As information criteria anomalies are detected, FFC enhances decision maker perception of quality by providing meta cues (criteria cues associated with task specific information cues) and/or facilitating real-time feedback based information quality management.

I propose using FFC to document the delta in both human and machine decision maker decision quality (i.e., effective and efficent task completion) between a control group given a defined task using operational ISs across a spectrum of operational risks and an experimental group with FFC enhanced ISs doing the same.

KEYWORDS

Situation awareness/situation assessment; engineering; quality.

INTRODUCTION

Information technology (IT) dramatically alters how decision makers perceive the world, but how does that human or machine know if the information provided meets their task requirements? A variety of U.S. Department of Defense's (DoD) military joint publications (JPs) and policies acknowledge the impact technology has on the quantity and speed with which we acquire environmental data. Equally important, yet often overlooked, are the "perception-affecting factors" which provide contextual cues which allow data to be translated into information and knowledge as part of the overall decision making process.

Endsley elaborated on this theme in an assessment of situation awareness (SA) issues by stating, "…a major challenge will be providing sufficient information thorough a remote interface to compensate for the cues once perceived directly". Information quality is one such factor vulnerable to both malicious and non-malicious corruption and can be characterized by the criteria of accuracy, relevance, timeliness usability, completeness, brevity, and security as defined in JP 6-0 *Joint Communications System*. Cues on these criteria, provided in parallel with associated output information, allow decision makers to place their indirect observations in context for a given task, context which is frequently lost when real world events are reconstructed from sensory data.

Unfortunately, many of the information systems (IS) used by DoD have attributes which are disturbing given both the nature of military work and the risks associated with the loss of contextual cues. While it is impossible to create perfect systems that will always provide perfect information, at a minimum decision makers should at least be able to perceive the quality of the information provided by their ISs.

To that end, the goal of my research proposal is to use feed-forward control (FFC) to document the delta or difference in both human and machine decision maker decision quality (i.e., effective and efficent task completion) between:

1) a control group given a defined task using operational ISs across a spectrum of operational risks, and
2) an experimental group with FFC enhanced ISs doing the same.

FEED-FORWARD CONTROL

Endsley's SA data flow in system design diagram in Figure 1 describes how cues about our environment reach decision makers along one of three paths; direct observation via the decision maker's five senses, indirect observations from another observer, or indirect observations from a system (i.e., man-made representations).

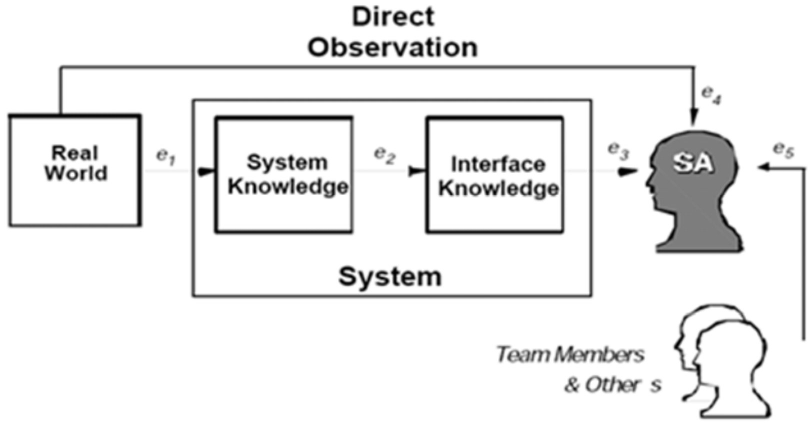

Figure 1. Endsley's situation awareness data flow in system design

Regardless of the type of indirect observation system used, a loss of context is inevitable. Without a data assessment and information quality criteria cueing process based upon task requirements, decision makers are provided with stark choices. One choice is to assume the data provided by the indirect observation system meets task requirements for quality, SA development, and decision making. The other choice is to employ resources (e.g., time, cognitive capabilities, etc.) which are often limited in naturalistic decision making (NDM) situations and attempt such deductions on their own.

A key question for systems engineers becomes how to identify and document the mechanisms used in an IS to create and translate ancillary evidence, such as information quality criteria taken from military doctrine, into the visual, audible and tactile cues need to enhance decision maker perception?

FFC in Context

First proposed by Ashby as a process to improve control over systems, the FFC process represented in Figure 2 senses disturbances and takes specific actions based on predetermined input minimum and/or maximum values for desired output requirements.

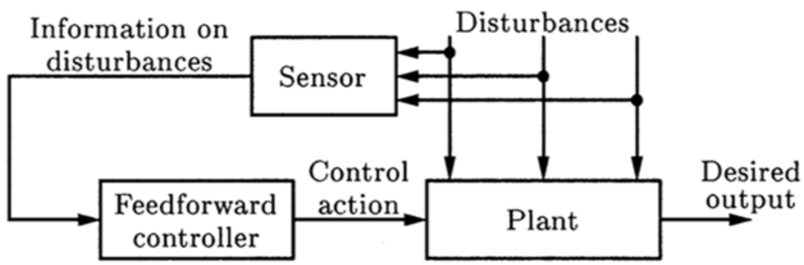

Figure 2. Kabamba et al's feed-forward control model

Unlike traditional feedback control where inputs are taken from a system's output to deduce needed corrections, FFC uses internal sensors with pre-determined user requirements stored in the controller to monitor the system's input for disturbances (i.e., differences between actual and desired input). This disturbance monitoring occurs before inputs enter the system so FFC can mitigate or cue input errors as required. When input disturbances detected by the sensor exceed the values in the controller, the controller sends a control action to the plant or process area of the system. The specifics of the control action can vary widely depending on the process being executed in the plant.

Historically, FFC was first incorporated into physical systems (e.g., electrical, hydraulic, mechanical, etc.) utilizing disturbance detection and input requirements to facilitate the application of corrective measures prior to the input reaching the system (e.g., increase voltage, decrease pressure, etc.). Such control actions can be numerous and varied. For the example above, the feed-forward controller could also generate a signal or cue about the status of the input based on user requirements. Or, the cue could be the only control action taken depending on the design of the system.

Most topics of study in the area of FFCs have been with industrial or engineering applications. Lerch and Harter used FFC in cognitive support systems to project future states of the system in an effort to reduce the cognitive workload of the decision maker. Brosilow and Joseph researched effects of an internal system disturbance and demonstrated that FFC could reduce disturbances better than feedback alone. Also, research involving a feed-forward model based on the predictability of disturbances incorporated into artificial neural networks has been documented.

This secondary application of using FFCs to create decision maker perception cues for system input disturbances, such as quality in an information system, becomes profound in the context of not only a user's SA of system operations, but also SA of that system's information quality. Despite indications of the use of FFC to provide evidence of information quality through the generation of information quality cueing, the use of feed-forward control within information systems, to either mitigate disturbances or create indicators, is not documented as part of the Endsley situation awareness data flow diagram in Figure 1.

Wickens and Holland state, "…one quality of good decision makers is that they will often be aware of what they do not know". With that in mind as a guiding principle, a research plan was developed to document information cueing processes not explicitly identified as part of the Endsley SA data flowdiagram. It is my position that the lack of a theoretical model incorporating feed-forward control in the situation awareness information flow process facilitates poor mental models and undermines the inclusion of FFC in decision support tools and indirect observation systems. Evidence from literature shows a limited awareness of feed-forward control and documenting the limited DoD use of quality criteria, lack of information quality criteria requirements, and overall lack of information quality cues in general strongly supports this conclusion.

While the Endsley diagram in Figure 1 may be representative of many indirect observation systems, the illustration used is an over simplification of what is often a much more complex information flow process. So much so, the omission of critical processes essential to FFC perception cue creation and display at the initial stage of creating decision maker SA may have a negative impact on desired decision making outcomes if such processes are left unacknowledged or are merely assumed to be in place. The last point about decision makers assuming the existence of perpetually perfect outputs from their information systems is the basis behind the original inception of my information quality based research beginning in 2003. This case study is a continuation of my previous work on issues of information integrity in time constrained decision making and subsequent applied research into poor data quality impacts on decision maker uncertainty.

To bridge the void between FFC and Endsley's existing data flow diagram, I first designed and presented a *Data Flow Model for Indirect Observation using FFC* at the annual meeting of the DoD Human Factors Engineering (HFE) Technical Advisory Group (TAG) in 2007. The current iteration of this model in Figure 3 is a hybrid of Endsley's diagram in Figure 1, Kabamba et al's model in Figure 2, and obseravations from case study research I conducted at a major U.S. military command and control facility in 2010.

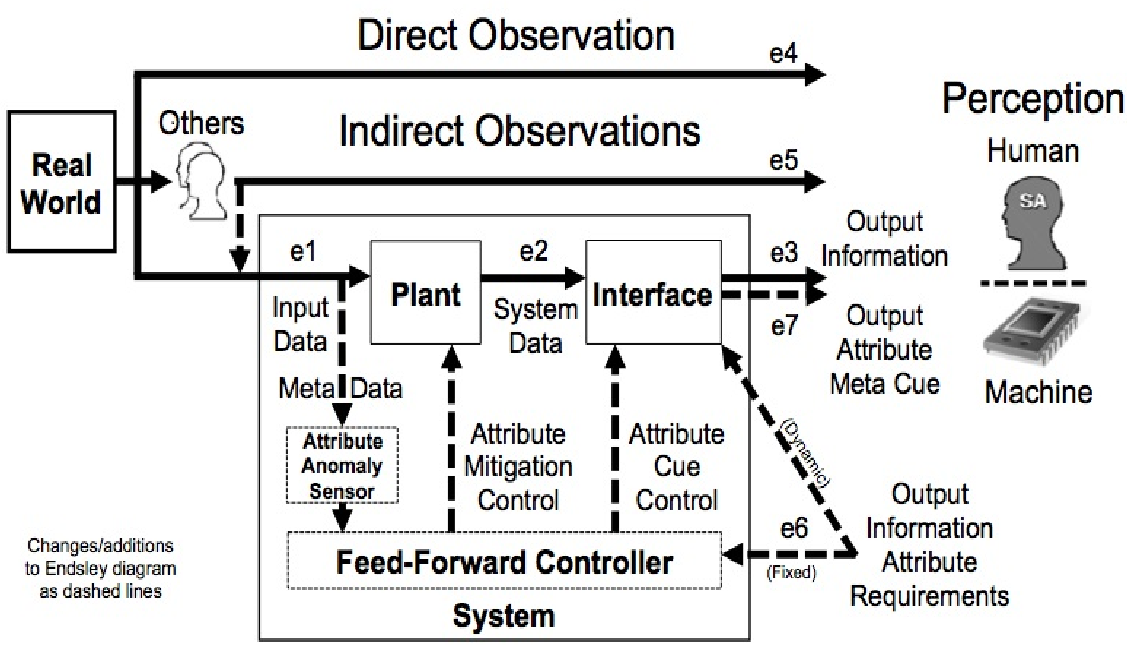

Figure 3. Perception of Information Attributes Using Feed-Forward Control

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The model includes the three required flow paths associated with the Feed-Forward Controller.

- User defined task specific information output attribute (i.e., quality) requirements (e6)
  - *weather based safety of flight decisions require awareness of data age and geographic origin*
- Meta-data from input data in order for FFC sensors to detect information attribute disturbances (e1)
  - *disturbances to observation meta-data (i.e., time stamps or geo-location) trigger meta-cues*
- Information attribute meta-cue output from the user interface (e7)
  - *FFC generated meta-cues highlight disturbances to the desired attributes of observations*

A loss of any of the three would result in the failure of the FFC to provide cues on information quality to the user. An additional flow path is that for FFC optional control actions should the system be capable of correcting detected disturbances in flow quality (i.e., replace the poor quality system input information with information that meets input requirements).

The critical need for policies governing the implementation of information quality cues and the incorporation of FFC generated cues to support decision maker tasks became apparent to many of the case study participants during the actual evidence collection activities. None were more impacted that those who realized they operated with systems that had no FFC information quality cues, were dependent upon cues originating from the observations of others, or had fallen victim to false cues.

EXAMPLES OF DATA FLOW PATHS

FFC support to SA of lightening stikes as required by decision makers for safety of flight.

Figure 4. Vaisala's Lightening Strike Input Data Flow Path (www.vaisala.com)

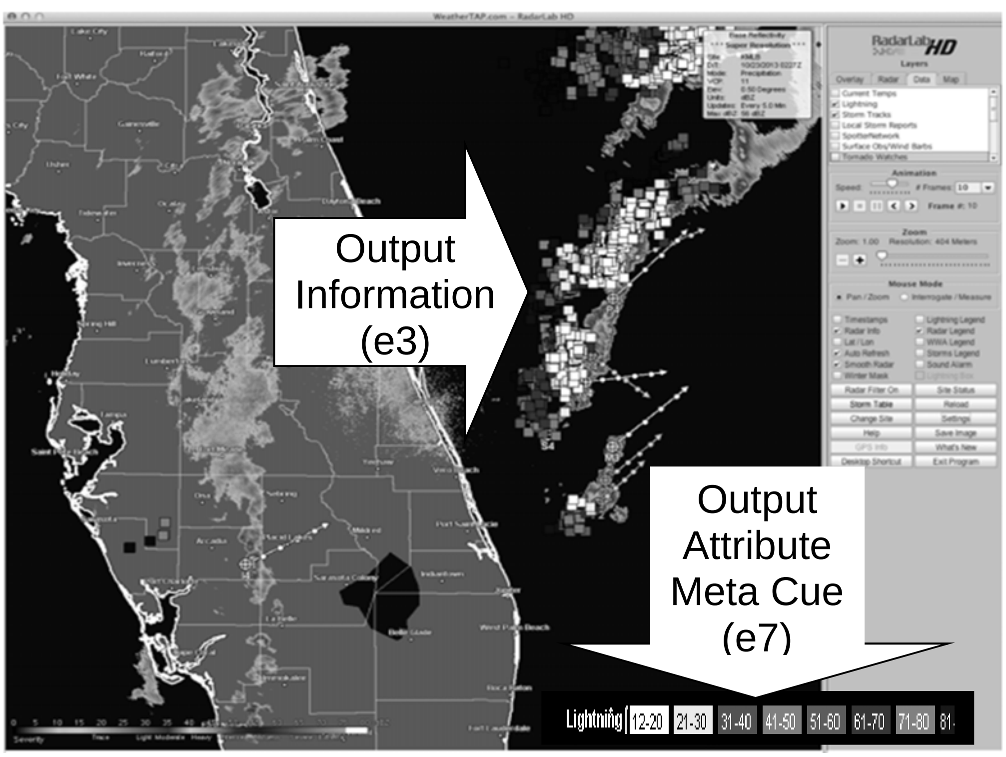

Figure 5. Interface Output Information and Attribute (www.weathertap.com)

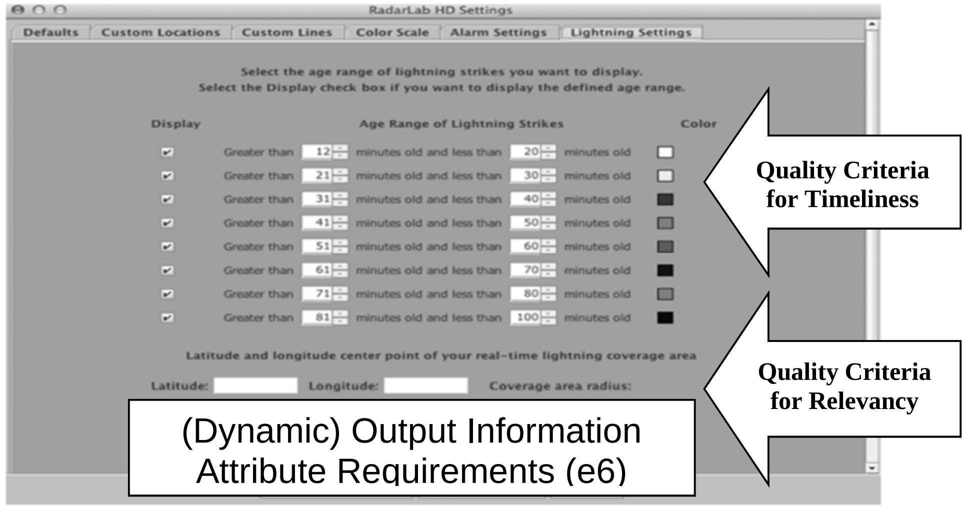

Figure 6. Output Attribute Requirements Interface (www.weathertap.com)

RESEARCH RECOMMENDATION AND CONCLUSION

The lack of polices regarding information quality, both DoD wide and internal to the case study organization, suggest the need for immediate guidance in the areas of metrics and requirements to feed FFC based processes.

- DoD wide policy for information quality metrics from meta-data generated as close to the point of data creation or change as possible to include negative responses informing users when such meta-data is not available so as to create uniform quality metrics for FFC assessment
- DoD wide policy for critical C2 systems to regularly document mission or task information quality criteria requirements so as to define operational information quality criteria used to populate FFC controllers
- DoD wide system engineering requirements that FFC based cueing processes be assessed in all information system development, deployment, and upgrade phases so as to create a mechanism for systems to provide information quality cues

It is for these reasons I propose experimentation using FFC to document the delta in both human and machine decision maker NDM decision quality (i.e., effective and efficent task completion) between a control group given a defined task using operational ISs across a spectrum of operational risks and an experimental group with FFC enhanced ISs doing the same. Without first baselining decision quailty with and without FFC, it becomes impractical for organizations to effectively assess those attributes of the operational environment (i.e. cyber key terrain) having the greatest impact on decision making. This is the essence of decision assurance.

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