META-INFORMATION REPRESENTATION AND COMMUNICATION

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Increasingly, the study of cognition and action in complex sociotechnical systems has revealed that humans reason about both information and the qualifications of that information. These qualifications, or *meta-information* (e.g., pedigree, recency, uncertainty), play a role in human performance across work domains (Pfautz et al., 2006). Meta-information contextualizes information, and therefore can critically influence how a human will process, understand, and act on that information. This panel will discuss the role of meta-information in the design and evaluation of visualization and decision-support systems.

PANEL SUMMARY

Human decision-making in real-time, dynamic environments is increasingly requiring sophisticated information management skills, as new technologies generate ever-larger amounts of potentially relevant heterogeneous data. Decision-makers must perceive, filter, aggregate, and organize this incoming information, while integrating it with previously gained knowledge to develop an understanding of the current situation. With this understanding, the decision-maker develops and selects a course of action that he or she believes will lead to a successful outcome. The ability to successfully decide on an effective course of action depends on the decision-maker's skill and experience in processing and understanding information and on the ability of any decision support system or display system to effectively present that information

The decision-maker, and therefore the systems supporting the decision-maker, must rely not only on understanding the domain-related information but also on the *qualities* of that information (e.g., recency, reliability, source), or the associated *meta-information* (Pfautz et al, 2005; Pfautz et al. 2006). Such qualities contextualize information, and therefore can critically influence how a decision-maker will process, understand, and act on that information (Guarino et al., 2006). For example, Juan decides to go for a walk despite an email from Jill describing it as "freezing out" because this comment comes from Jill, who is originally from a warm climate and is highly sensitive to the cold. The information, "it is freezing out," is qualified by its source, Jill, and Juan's reasoning is impacted by his prior knowledge of that source. If the source of the information or knowledge about that source changes, the information may result in different perceptions, reasoning, and action from Juan.

This simple example represents but one of many cases of how meta-information can impact reasoning. In the recent literature, others have focused on the role of one type of meta-information, uncertainty, on human perception and cognition and the resulting implications for system design. For example, a number of efforts have attempted to describe how the design of systems to aid in reasoning about the impacts of weather necessarily must represent uncertainty (e.g., Lefevre et al., 2005; Shunn, Kirschenbaum, & Trafton, 2005, Thomas-Meyers, 2005). In addition, other efforts have attempted to describe and evaluate approaches to the visualization of uncertainty (Bisantz et al. 2006; Bisantz, Marsiglio, & Munch, 2005; Finger & Bisantz, 2002; Trickett et al. 2005).

To differentiate between uncertainty and the prior work associated with understanding human reasoning about uncertainty and the portrayal of uncertain information, we have developed a set of working definitions to help establish the concept of meta-information relative to other terms currently in use in the cognitive work analysis community. These terms, adapted from (Pfautz et al. 2005; Pfautz et al. 2006) are:

- *Data* is output (processed or unprocessed) from a human or machine system that may or may not be useful in the decision-making process (e.g. radar reports atmospheric conditions of (x, y), Joe says a storm is coming, etc.)
- *Information* is recognized inputs that are necessary or usable in a directed decision-making process or behavior (e.g., a storm is coming that may affect the UAV's flight capabilities)
- *Meta-data* is characteristics or qualifiers of data that may or may not be useful in the decision-making process (e.g., ground-based radar Y can only locate aircraft with an error of +/- 1.5m)
- *Meta-information* is characteristics or qualifiers of *information*, affecting a human's:
  - Information processing (e.g., reports flagged as "important" are used first)
  - Situation awareness (e.g., because information about wind speed is recent and certain, the model can ascertain which towns are threatened by tornados)
  - Decision-making (e.g., because information about the adversary's location is 30 hours old, the model must actively gather new information before moving into that location).

These definitions are dependent on the particular cognitive task and the context in which that task is performed. Nevertheless, they serve to explicitly identify the critical role of meta-information in human decision-making.

Recently, some initial efforts have tried to focus more broadly on the analysis of meta-information and its role in human reasoning in certain application domains (e.g., military intelligence (Pfautz et al. 2005) and command and control (Pfautz et al. 2006, Guarino et al. 2006)). Similarly, work on the design and evaluation of decision-support systems that incorporate visualization of meta-information (Thomas-Meyers & Whitaker, 2006) is progressing, with evaluations of initial display methods well under way (Bisantz et al., 2006).

To assess the state of the art in understanding, analyzing, and design systems with respect to the role of meta-information, we have gathered a set of practitioners and researchers to present recent work and stimulate discussion (Note that some panelists will discuss "uncertainty" as one form of meta-information). Each panelist will present the critical aspects of their work as it relates to the concepts of meta-information defined here, followed by a discussion session.

Panelist #1: Prof. Ann Bisantz
Evaluating Meta-Information Visualizations

In many domains, operators need to understand and act on large volumes of information from a variety of sources. Operators are particularly challenged by the need to reason about the qualifiers of that information. These qualifiers, or "meta-information" (Pfautz et al., 2005), include characteristics such as the uncertainty associated with data, the age of the data, and the source of the data. Over the past several years, we have engaged in a research program that has included experimental studies of how specific components of visual representation (for instance, aspects of color, transparency, and salience). To date, results have indicated that users can reliably rank order regions coded to represent different levels of meta-information, when codes are based on different graphical components (e.g., color saturation, transparency) but that there may be framing effects in terms of ordering direction.

Further research to clarify aspects of meta-information type, framing, salience (due to background-foreground differences); and absolute color value will be presented.

Panelist #2: Dr. Cullen Jackson
Representing and Visualizing Uncertainty in Dynamic Targeting

In recent work, we researched methods for modeling uncertainty in complex systems, techniques for visualizing uncertainty, and the Air Force dynamic targeting process as an exemplar complex system. The dynamic targeting process requires multiple decisions to be made at various levels and locations, and rapid coordination between command and control and tactical elements. These decisions are made under time pressure and are vulnerable to uncertainty in many ways. For example, targets can be mobile, they can vary in priority, and they can vary in risk. Subsequently, we developed a demonstration of techniques for visualizing the uncertainty associated with dynamic targeting. VUE (Visualizing Uncertainty in dynamic Environments) was designed to support a warfighter’s situation awareness of the degree of uncertainty associated with a specific target for dynamic targeting, as well as the amount of time required to resolve the uncertainty to a reasonable level.

Panelist #3: Dr. Gina Thomas
Glyphs, Military Symbology, and Meta-Information Visualization

The concept of net-centric operations requires innovations in both the technical and knowledge areas (cf. Net-Centric Joint Force Concept - NCJFC). MIL STD 2025B specifies standard symbology for depicting joint force units. This symbology is constrained to coarse-grained depiction of single elements and embedded semantics are limited. There is a need for intermediate representations more detailed than the MIL STD 2025 elements, yet capable of providing readily understood summary information to afford warfighters the knowledge and shared understanding demanded in net-centric operations. In addition, various types of meta-information such as uncertainty with regard to the current and future states of the battlespace, uncertainty with regard to the current state of the battlespace representation itself, age of the data underlying the representation, and deficiencies (gaps, omissions) in the data should be portrayed in a way that allows ready understanding of the current situation and likely effects of prospective courses of action.

In an attempt to provide a coherent method of portraying meta-information in the C2 environment, Air Force Research Laboratory Human Effectiveness Directorate has defined a symbology set, which we refer to as knowledge glyphs. The term 'glyph' is used to denote a structured representation coded to portray relevant semantics (i.e., 'knowledge') of the associated battlespace object(s). Such objects may be physical entities, collective forces, or states of the battlespace environment. Knowledge glyphs are intended to serve as standardized 'micro-interfaces' informing users on specific objects the way on-screen displays inform them on collective battlespace states.

Panelist #4: Dr. Greg Trafton
Using Spatial Transformations to Deal with Uncertainty

One interesting feature of complex visualizations is that there is an enormous amount of data on them (a typical complex visualizations has 1000's to 100,000's of data points on it). However, because of the data density, it is quite difficult to display explicit representations of uncertainty. For example, most typical meteorological visualizations (e.g., weather charts) do not show uncertainty. These meteorological visualizations are used by experts to forecast the weather, which is inherently an uncertain proposition. I will present a study that examines how experts and novices (journeymen) in meteorology deal with uncertainty. We find that a common method for dealing with uncertainty is to use spatial transformations to mentally manipulate aspects of the visualization to match the users' understanding of the situation. By understanding how people deal with uncertainty and use spatial transformations, we can build visualization tools to help people deal with that uncertainty. I will highlight several theoretically derived tools that we are building to help deal with uncertainty.

Panelist #5: Dr. Randall Whitaker Meta-Information for Providing Contextual Cueing

'Meta-information' can be provided to qualify or enhance data pertaining to a given entity being portrayed in an advanced C2 visualization. However, there may be multiple referential contexts that can be considered to 'intersect' at or with the given entity. For meta-data to be readily useful, the user must associate it with the most pertinent context of evaluation. For example, auxiliary meta-data provided for a specific armored vehicle may describe (e.g., the certainty or recency of its battlefield position (geospatial context), its weapons range (tactical context), and/or its unit affiliation (organizational context). Advanced C2 visualizations need to incorporate contextual cueing - and perhaps even multi-contextual portrayals - to aid decision makers in avoiding cognitive overload and errors by facilitating representational clarity.

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