Hypothesis Mapping and Visualization[1]

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ABSTRACT

We have constructed a hypothesis visualization and mapping tool called DECIDE™ that combines structured argumentation with the analysis of competing hypotheses and Bayesian hypothesis scoring to enable analysts to perform more rigorous analyses. The tool provides a workflow for analysts to evaluate evidence for credibility and believability, associate evidence with the hypotheses, create arguments, and score the arguments. Users manipulate the hypotheses, evidence, and their associated arguments using visualization techniques and, thereby create well-reasoned analyses.

1 INTRODUCTION

An argument ties *facts* and *evidence* to a *conclusion* via a logical sequence. The goal of DECIDE is to present this sequence by showing the relationships among facts, evidence and the hypotheses. DECIDE shows the structure of an argument, its evolution through time, the strength of the supporting evidence and alternative arguments. It also identifies missing, weak, negative evidence, uncertainty and faulty argumentation caused by biases and assumptions. Effective hypothesis visualization will highlight weaknesses in analysis, contradictory evidence, and suggests "holes" that can be filled with additional investigation.

2 EVIDENCE, HYPOTHESES, AND ARGUMENTS

The essential aspects of an analysis consist of four components: Evidence, Hypotheses, Arguments, and Argument evaluation.

Evidence

For robust analysis it is critical to rate evidence to assess its believability. DECIDE enables analysts to rate evidence along thee dimensions. The evidence *Source* is evaluated for the credibility of who or what the information is coming from. The evidence *Applicability* pertains to the possibility that the event could occur. The *Confidence* is an assessment made by the analyst that given the overall believability of the event and source, the evidence has been processed in the intelligence community thoroughly and has not been impaired. These ratings are combined into a single believability score.

DECIDE Evidence Rating Dialogue

An early complaint from DECIDE users was that it was too difficult to enter evidence into DECIDE. A second problem was that evidence reports were too coarse and that more granular methods were needed to mark particular sentences in evidence reports. To address these issues we created the DECIDE Microsoft Office toolbar. The DECIDE toolbar attaches to Microsoft Word and enables analysts to mark particular sections of a document. The analysts can set evidence properties for the highlighted text and can then send this evidence directly to DECIDE. Using this feature analysts can identify key phrases in a document that are essential for an argument and use DECIDE to link the evidence text back to original text in the raw document. The toolbar works seamlessly with Microsoft Word to maintain the markings as part of MS's internal formats.
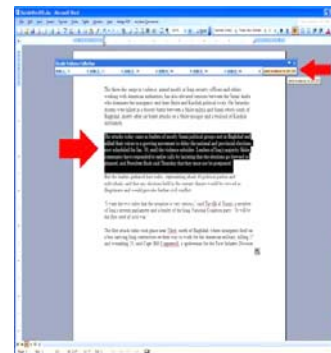
DECIDE MS Word Toolbar

Hypotheses and Sub-hypotheses

Hypotheses are assertions from an observer. Hypotheses may involve alternative possible explanations, possible answers, or alternative estimates. Hypotheses may have substructure. It is sometimes possible to partition a high-level hypothesis into a set of sub-hypotheses. The substructure decomposition is always a hierarchical tree. The hierarchy may be several levels deep before bottoming out in questions that can be directly assessed and answered by evidence.

Arguments, and Inference Networks

An *argument* consists of a set of inferences that captures the chain of reasoning which connects evidence with a hypothesis. The strength, weight, or force of an inference is related to the evidence's credibility and its relevance to the hypothesis. Evidence with weak credibility and weak relevance cannot have strong inferential weight. An *argument*, sometimes called an *inference network,* may be represented using a directed acyclic graph (DAG) where the nodes represent hypotheses, sub-hypotheses, and evidence and the edges represent inferences. The proof state of any argument is the likelihood that the ultimate hypothesis in the inference network is true.

DECIDE supports both Wigmore (1931) and Toulmin (1958) argument forms and provides visualizations for each. DECIDE implements Wigmore arguments using graph structures where hypotheses and sub-hypotheses are represented by colored spheres

and evidence is represented using cylinders. Visual characteristics of the evidence glyphs and display highlight important properties of the evidence and argument. In DECIDE's implementation, for example, dashed lines indicate negative or conflicting support for the hypothesis. It is important that the analysts investigate hypotheses and sub-hypotheses with excessive amounts of conflicting evidence since it may suggest denial and deception or perhaps lead the analyst to consider a new hypothesis.
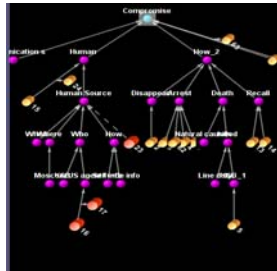

Wigmore
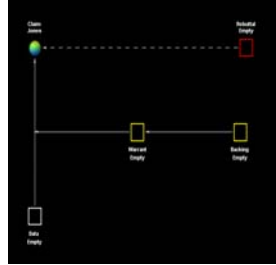
Toulmin

DECIDE's Visualization of Argument Forms.

3 CONSTRUCTING ARGUMENTS

Constructing an argument is a creative task that involves looking at evidence, formulating conjectures, creating hypotheses, associating evidence with hypotheses, creating sub-hypotheses, and iterating. The most successful environments will encourage analysts to explore new hypotheses and alternative explanations for the evidence. The tasks for argument construction involve:

- *Browsing Evidence* using searching, sorting, filtering, reordering to navigate through sets of evidence.
- *Creating Hypothesis* and sub-hypotheses that is consistent with the evidence.
- *Associating Evidence with Hypotheses* and also with the sub-hypotheses.
- *Building arguments* that capture the relationships among the evidence, hypotheses, and sub hypotheses.
- *Assigning evidence relevance* and *credibility parameters* so that the argument can be evaluated.
- *Scoring the argument* and identifying its strengths and weaknesses.
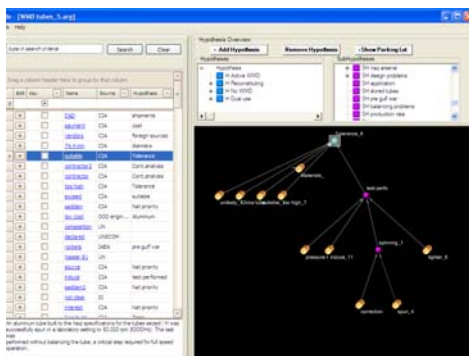
DECIDE's "drag-and-drop" interface for Constructing Arguments

To make it easy to create argument DECIDE provides several evidence marshalling visualization tools. These tools include link analysis visualizations, time lines, and interactive lists. They enable analysts to sort through the evidence to identify relationships.
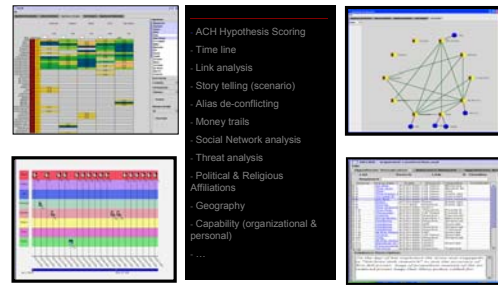
DECIDE Evidence Marshalling Tools.

4 COMPARING ARGUMENTS USING HYPOTHESIS ANALYZER

Heuer's (1999) Analysis of Competing Hypothesis is a technique for marshalling evidence, developing alternative hypotheses, and associating evidence against hypotheses. Heuer suggests creating an evidence-by-hypothesis matrix display with evidence on the rows and hypothesis on the columns. In our implementation, as suggested by Waltz (2003), we added columns for evidence credibility and evidence denial and deception, an integer between 1 (easily spoofed) and 10 (impossible to spoof). The colored cells in the matrix display indicate evidence that is relevant to a hypothesis. The cell color may encode the relevance, inferential force, or both. The bar plots along the top show the current "score" of the hypotheses. We currently have two scoring functions (see below) that rate the hypotheses against each other (competing) or individually (multiple).

DECIDE's Hypothesis Analyzer

5 ACKNOWLEDGMENTS

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Wigmore, J.H. (1931). *The Principles of Judicial Proof*, 2nd ed., Boston: Little, Brown and Company.