

Graphical manipulation of evidence in structured arguments

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A semiautomated approach to evidential reasoning uses template-based structured argumentation. Graphical depictions convey lines of reasoning, from evidence through to conclusions.

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1. Introduction

Over the past eight years, we have been investigating the use of *template-based structured argumentation* as a means of capturing and guiding collaborative analysis. The idea is to capture best analytic practice for a given class of problems in a template and then use that template as the basis for collecting evidence and drawing conclusions about specific situations. Unlike our earlier work that focused on automating human uncertain reasoning [Lowrance, Garvey, & Strat 1990, Gister Home Page], this approach focuses on recording and coordinating human reasoning. A key aspect of this has been the use of graphical depictions of arguments to rapidly convey the state of lines of inquiry, from evidence to conclusion, highlighting information needs as well as the evidence that drives the conclusion. To support this approach, we created a collaborative software tool called the Structured Evidential Argumentation System (SEAS) [Lowrance, Harrison, & Rodriguez 2001, SEAS Home Page]. Using this tool, contributing analysts directly manipulate depictions of arguments, adding and interpreting evidence relative to questions raised by the template, debate and draw conclusions based upon the collective evidence, and finally use these depictions to convey their findings to decision makers.

Our original focus was on aiding intelligence analysts addressing issues pertaining to national security. But we have since discovered that these same techniques have broader applicability. In particular, we have applied these techniques to assemble and draw conclusions from evidence pertaining to detecting workmen's compensation fraud, tax code compliance risk [Lowrance & Ragoobeer 2004], and information collection/sharing among emergency first responders. Although we have yet to implement these techniques, we believe that they should also be applicable to various aspects of legal reasoning.

Here we summarize our approach to supporting evidential reasoning, highlighting the graphical depictions that we use to develop and convey lines of reasoning.

2. Capturing analytic methods as arguments templates

Our approach is based on the concept of a *structured argument*. While others before us were exploring structured argumentation concepts, particularly the notion of argument mapping [Wigmore 1937, Toumlin 1958, Kirschner, Buckingham Shum, & Carr 2003], our approach generally departed from theirs in being template driven. Our structured arguments are based on a hierarchy of questions (a tree) that is used to assess a situation. This hierarchy of questions is called the *argument's template* (as opposed to the *argument*, which answers the questions posed by a template). This hierarchy of questions supporting questions may go a few levels deep before bottoming out in questions that must be directly assessed and answered. These are multiple-choice questions, with the different answers corresponding to discrete points or subintervals along a continuous scale, with

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one end of the scale representing strong support for a given proposition and the other end representing strong refutation. Leaf nodes represent primitive questions, and internal nodes represent derivative questions. The links represent support relationships among the questions. A derivative question is supported by all the derivative and primitive questions below it. Figure 1 illustrates a thirteen-question argument template, with nine primitive questions and four derivative questions. Note that question 1 is answered based upon the answers to 1.1, 1.2, and 1.3, and 1.3 is answered based upon the answers to 1.3.1, 1.3.2, and 1.3.3.

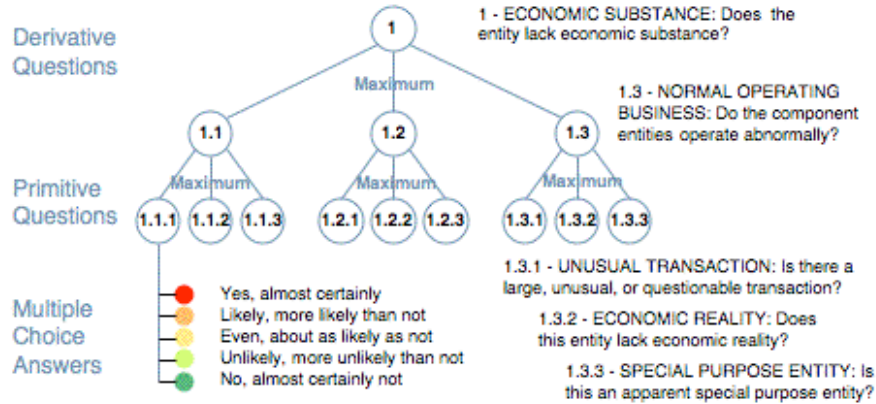


Figure 1: An example argument template

As pointed out by Morgan D. Jones [Jones 1995]: "Structuring is to analysis what a blueprint is to building a house. Would you build a house without a blueprint? You could, of course, but there's no telling what you'd end up with. Building a house, building anything, without a plan is, to say the least, ill advised." An argument template serves as a blueprint for the construction of arguments. It reminds the analyst of the full range of factors that should be included and how they relate to one another. As such, it can guide a novice in addressing an unfamiliar assessment task and it can prevent an expert from jumping to a conclusion before all aspects of a problem have been fully considered. In addition, if two analysts independently construct arguments for the same problem based upon a common template, they can be rapidly compared and contrasted, particularly through graphical renderings. Some templates are very abstract, serving more to organize a person's thinking than to guide it. Other templates are quite specific, posing detailed questions that can be used to guide a novice, imparting best practice. For example, a template originally developed by U.S. intelligence analysts, to assess the threat imposed by a particular terrorist group, was brought into our laboratory. There it was successfully generalized and applied by non-experts to assess the threat imposed by a different terrorist group, demonstrating how novices can be quickly brought up to speed, on an unfamiliar problem, given a high-quality template.

There are two distinct ways of approaching the structuring of an argument template: top-down and bottom-up. Using the top-down approach, one starts with the central question and attempts to break it down into a small set of supporting questions, each of approximately the same significance; then one breaks down each of those questions, attempting to break each into the same number of equally significant questions. This procedure continues until questions are produced that can be directly answered or until the number of overall questions has become too numerous to include in a single template. In this latter case, the author might elect to limit the depth of the original template and then capture those elements that fell below that depth limit in their own templates; each of these *cascaded templates* would share its root question with one of the primitive questions in the original

template. The relationship of these cascaded templates to the original template can be captured by adding these to the original template as *discovery tools* (more on this below). As such, an analyst who is developing an argument based upon the original template, and is confronted with one of its primitive questions, can either elect to directly answer the stated question or invoke one of these discovery tools to further break down the question. The advantage of this approach is that the analyst determines which of these discovery tools to employ, thus choosing where and where not to spend additional effort. An analyst might choose to delve deeper, using a cascaded template because he or she cannot directly answer the primitive question and needs guidance in breaking it down to questions that can be answered. Or, the analyst, believing that this is central to the problem at hand, wants to be very deliberate in his or her reasoning.

Using the bottom-up approach, one starts by enumerating the detailed conditions that should be considered. Once these are enumerated, one begins to cluster these into coherent collections of roughly equal size and significance. One then clusters the clusters, again striving for clusters of equal size and significance, and continues this process until a single cluster remains. Each cluster should give rise to a question in the resulting template, with the nesting of the clusters captured as supporting questions.

In practice, neither the top-down nor bottom-up approach is typically employed in its pure form. Instead, both are employed at different times, one after the other, until a satisfactory result is achieved. Once the overall skeletal structure has been established, the analyst's attention should turn to writing the detailed questions and answers for the template. In practice, we have found that analysts are capable of authoring templates after minimal training, but that authoring high-quality templates is challenging and requires additional experience.

An *inference method* completes an argument template. It is used to automatically answer some questions based upon the answers to other questions. The analyst answers the primitive questions in the question hierarchy, and the answers to the derivative questions are automatically calculated. A typical inference method might take the maximum, minimum, or average (i.e., worst case or best case or average case) answer as the conclusion when combining the answers to several questions assessed along a continuous scale. We favor such simple inference methods over more complex methods (e.g., ones based upon conditional probabilities) since they are easier to follow and explain. This reflects our goal to organize and record human reasoning rather than attempting to automate it.

To facilitate the rapid comprehension of arguments, we use a traffic light metaphor relating answers to colored lights along a linear scale, from green to red. The questions in a template are typically yes/no or true/false; the multiple-choice answers for primitive questions partition this range, associating an answer with each colored light. Typically, a five-light scale is used (green, yellow-green, yellow, orange, red). Here green might correspond to false, red to true, and the other three to varying degrees of certainty. No multiple-choice answers are associated with derivative questions; within arguments, answers are strictly summarized by lights indicating degree of certainty.

Discovery tools can be associated with primitive questions in a template. In general, they are recommended methods for acquiring information relevant to answering the associated question. These might be links to Web pages, queries to databases or search engines, parameterized launches of other analytic tools, or references to cascaded templates. They capture an important aspect of an analyst's knowledge, namely, where and how to go about seeking information relevant to answering questions. Knowledge of this form is one thing that distinguishes an expert from a novice analyst. Discovery tools are captured on primitive questions within a template by storing the URLs that will launch them along with short textual citations used to reference them.

3. Capturing analytic products as arguments

Arguments are formed by answering the questions posed by a template. Answers are chosen from the multiple choices given in the template. If the available information does not allow the analyst to reduce the possible answers to a single choice, multiple choices can be selected bounding the answers that remain possible, given the available information. Upon answering each question, the template's inference method is applied, deriving the answers to derivative questions. Using the traffic light metaphor, arguments can be displayed as a tree of colored nodes. Nodes represent questions, and colors represent answers. Figure 2 shows one such tree. From such visualizations, one can quickly determine which answers are driving the conclusion. In this case, it is obvious that 1.3.1 is driving the answer to 1.3 and 1.3 is driving the answer to the root question (i.e., question 1). Within SEAS, if the cursor is positioned over a node in such a visualization, a small popup window displays the associated question. Thus, by moving the cursor across the argument, the line of reasoning driving the conclusion can be quickly determined.

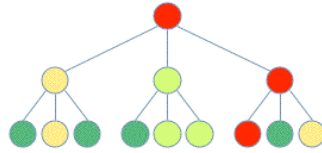


Figure 2: An example argument

When answering a question in an argument, the *rationale* for answering in that way is recorded in text with attribution given to the answering analyst and the time that that answer was given (Figure 3). Information used as evidence to support the answers given in an argument is recorded as part of the argument. When information that is potentially relevant to answering a question posed is first found, it is entered as an *exhibit*. This can be any kind of digital document (e.g., text, image, video, audio, spreadsheet) or a simple reference to a paper document. An exhibit assigns a unique identifier to the information, uploads the document for later access if it is in digital form, and records a *citation* (i.e., string of text) for referencing it (typically consisting of some combination of title, author, and date). When the *relevance* of the information to the question at hand is determined, the exhibit is promoted to *evidence*. The relevance is recorded in two ways: as text explaining the significance and as the answer(s) to the question that would be chosen if the answer were to be based solely upon this evidence. The analyst making this assessment and the time of the assessment are recorded as well. When evidence is present, the rationale typically explains how the collective evidence supports the answer(s) chosen, explaining away that evidence that contradicts the answer and weaving together the supporting evidence to arrive at the stated conclusion.

When a new exhibit is first attached to an argument, a red signal flag is raised to indicate that analyst attention is needed to determine its relevance. These flags are shown in the graphical visualization of arguments until the exhibits are promoted to evidence or until the flags are dismissed. Dismissing a flag on an exhibit indicates that the exhibit was found to not be relevant to answering the associated question. Retaining the exhibit with its lowered flag provides a record of this determination.

When discovery tools are present, they can be used to aid in the collection of evidence. If the discovery tools are of the *auto-populating* variety, when triggered they automatically turn all the “documents” that they return into exhibits with raised flags. Within SEAS, all such auto-populating discovery tools associated with an argument can be triggered at once, then the signal flags in the graphical depiction of the argument guide analysts to the locations within the argument where new information is waiting interpretation. When discovery tools are based upon cascaded templates,

cascaded arguments result from their triggering. In this way, the analyst can choose where to do a more thorough analysis, delving more deeply in a targeted way. A cascaded argument's conclusion can be automatically used as its relevance in support of the higher-level argument.

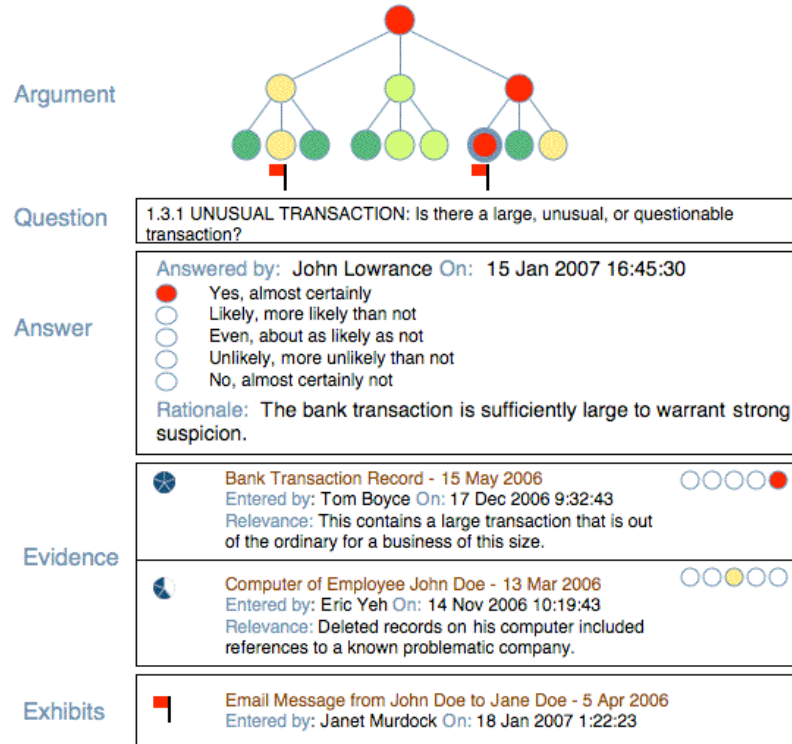


Figure 3: An answer to a primitive question in an argument

The analyst also chooses a *fusion method* for combining all the evidence gathered supporting a single question. The fusion method can be manual (i.e., the analyst answers the question based on his or her understanding of the evidence and its relevance) or automated (i.e., the answer is automatically reached by applying a combination method to the relevance of the supporting evidence). When an automated method is in use, changes to the supporting evidence, including changes in supporting arguments, can ripple up through the argument that they support, changing the conclusions. Such changes are immediately visible in the graphical depiction of the argument.

Given that not all sources are equally credible, weights are useful in recording their presumed credibility. These are graphically depicted by circular symbols, filled to varying degrees, associated with each piece of evidence, the weight being proportional to the area filled (see Figure 3). Within SEAS, clicking on one of these symbols permits one to choose from five different weights. In addition, some automated fusion methods are sensitive to these weights (e.g., weighted average). When these are in use, a change to the weight associated with a piece of evidence causes the answer to the question to be recalculated, along with all the derivative questions that depend upon it. However, using weights to capture estimates of source credibility has proven to be extremely useful even when questions are answered manually. In addition, weighted fusion methods can be utilized within

the inference methods of argument templates. Here they capture the idea that the answers to some supporting questions are more important than the answers to others when arriving at a conclusion. The weights associated with supporting questions are chosen by selecting from the same symbols used to weight evidence; if less than full weight is attributed to a question in an argument, its node is drawn proportionally smaller in the tree of nodes that depicts the argument.

All the arguments and templates thus far discussed consist of a single hierarchy of questions, designed to arrive at the answer to a single overall question, the one uppermost in the hierarchy. In many applications, we have found it useful to employ a coordinated set of such *unidimensional* arguments, where each addresses a common topic from a different perspective, without attempting to roll these into a single overall answer. We refer to these as *multidimensional* arguments. For example, the assessment of the stability of a nation state might best be addressed by several independent assessments of the leadership, social, political, military, external, and economic situations.

In a *starburst* graphic (Figure 4), the answers to the component arguments are organized in a pattern resembling spokes on a wheel. Each "spoke" corresponds to one answer; answers are displayed as "traffic lights" at the ends of the spokes; answers are also plotted as points along the spokes with the "hub" of the wheel typically corresponding to the green end of the linear scale and the "rim" typically to the red end; the points plotted on neighboring spokes are connected by lines, and the resulting polygon is filled. The result is a plot that visually conveys the argument, with the severity of the situation (typically) being proportional to the area of the plot. This technique invites rapid comprehension and comparison when multiple arguments are simultaneously displayed.

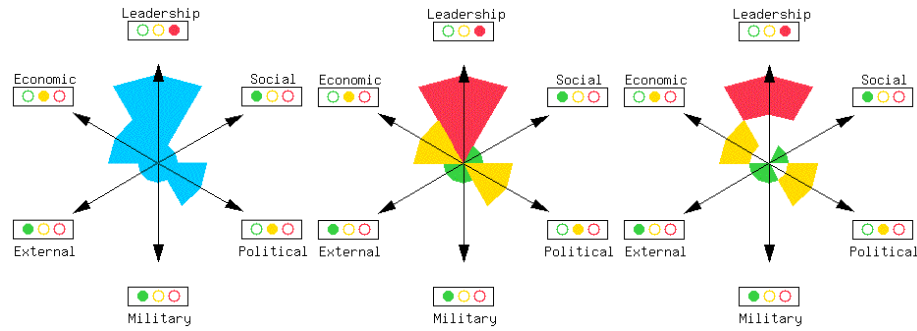


Figure 4: Starburst depictions of multidimensional arguments

The starburst can be customized in a number of ways. One can specify whether each segment of the starburst should be depicted as a ray, beginning at the origin and extending out to the appropriate position, according to which lights are lit, or as sectors, having only those areas filled whose corresponding lights are lit. You also can specify how different parts of the starburst should be colored: mono in blue, max with the color corresponding to the highest-valued light, min with the color corresponding to the lowest-valued light, own with the color that corresponds to that portion on the starburst (i.e., green at the center, yellow in the middle, and red at the perimeter).

A *constellation* is another way of graphically depicting a multidimensional argument (Figure 5). Using the same radial layout as for the starburst, it depicts the trees of lights corresponding to each component argument within the corresponding wedge, placing the root node/light nearest the origin and growing out from there. Larger nodes/lights are used nearer the origin. Although this can result in a cluttered display, it has the advantage of depicting every question/answer of a multidimensional argument within a single compact display. This is further enhanced by pop-ups, which appear when the cursor is positioned over any light, that display the corresponding question text. A

further refinement allows one to filter out lights based upon their corresponding color. Thus, for example, you might elect to show only the red, orange, and yellow lights, or just the red lights (i.e., the high-value information). Examples of this display appear in Figure 5.

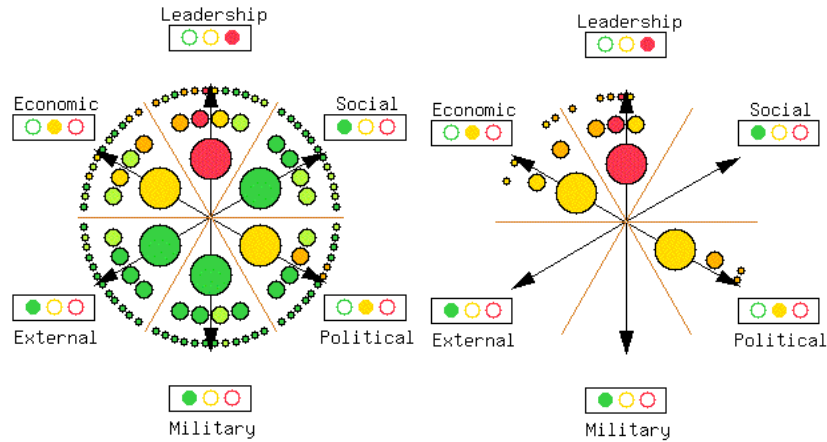


Figure 5: Constellation depictions of multidimensional arguments

Yet another effect can be achieved by overlaying constellations on starbursts (Figure 6). This allows the user to quickly grasp the overall argument through the starburst and the details through the constellation. While at first glance, these and the previous depictions of arguments might seem somewhat opaque, they have proven to be quite valuable, allowing one to quickly spot what is driving an argument, where one argument diverges from another, or what trend is developing across a sequence of arguments. This is particularly due to their compact nature, allowing multiple arguments to be viewed side by side, within a single screen/page.

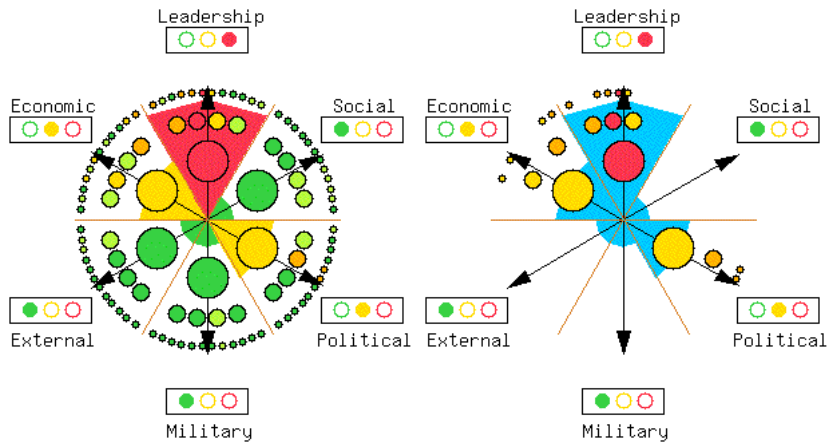


Figure 6: Constellation overlaid on starburst

While trees, starbursts, and constellations are particularly useful depictions for investigation online, where the corresponding question for each node/light is revealed upon positioning the cursor over it, these are less useful offline where no such information is available. To better convey the content of an argument offline, while striving to remain as compact as possible, we have developed a tabular argument summary (Figure 7). In a tabular summary of a unidimensional argument, the root question is captured by a single cell at the top that spans the width of the table; the questions that support it are each represented by a cell in the next row of the table; the questions that support each of those are represented by cells in the next row of the table, below the cell of the question they support; and so on. Each cell is labeled with the topic of its corresponding question and is filled with a color corresponding to its answer. Multiple such tables are used to summarize a multidimensional argument, and can typically be printed on a single page.

ECONOMIC											
MACROECONOMIC STABILITY			FINANCIAL STABILITY			ECONOMIC HEALTH			INFRASTRUCTURE/ENVIRONMENTAL PROBLEMS		
BUDGET CRISIS	INFLATION	BALANCE OF PAYMENTS	BANKING SECTOR	CURRENCY	STOCK MARKET/INVESTMENTS	OUTPUT	KEY SECTOR	UNEMPLOYMENT	INFRASTRUCTURE	NATURAL ENVIRONMENTAL CATASTROPHE	MAN-MADE ENVIRONMENTAL CRISIS

Figure 7: Table depictions of unidimensional argument

Another very useful means for conveying the contents of an argument is through a textual summary. Here questions are numbered and indented in outline style to reflect their position in the question hierarchy. The lights corresponding to the answer to each question are shown adjacent to each. Primitive questions also include answer rationale, along with the associated evidence and exhibits, and all their attributes. All are annotated with the contributing analyst and the time of the contribution. Thus, these capture the full contents of an argument, suitable for detailed review and as the starting point for a fully formatted textual report on the topic. Like constellations, one can choose to suppress the inclusion of questions whose answers are represented by certain colors. This provides a means to exclude the low-value information (e.g., near green) and focus on the high-value information (e.g., near red), allowing one to reduce the textual summary to those aspects that are driving the overall conclusions.

4. Supporting collaborative analysis

SEAS seeks to foster collaboration among analysts. In reviewing why analysts might seek out other analysts, we identified six reasons:

- To learn from others by reviewing their analytic methods and products
- To stimulate creative thinking by rapidly exchanging and generating ideas (i.e., brainstorming)
- To gain insights by having others critique their work
- To share the workload, and thus to get results quicker and to get superior results by having different people do what they do best
- To improve their understanding by comparing and contrasting their results with the results of others
- To improve the quality of their results by combining them with the results of others

Note that most of these activities stress the need for asynchronous collaboration aids. The most important capabilities for supporting collaboration in SEAS are through tools that aid argument or template understanding, argument or template comparison, argument or template merging, and argument or template critiquing, and that support division of labor regarding the creation and editing of arguments or templates.

From its inception, SEAS was designed as a collaborative tool aimed at supporting teams of analysts engaged in collective reasoning tasks. This is one of the reasons that it is architected as a web application, consisting of a web server with browser clients. All SEAS objects reside on the server.

Users access these objects using a personal computer, equipped with an industry standard browser, connected to the server via a network (e.g., the Internet). In response, the server generates dynamic web pages that are rendered by the clients to provide depictions of SEAS objects, and/or modifies these objects based upon client actions. SEAS provides asynchronous to near synchronous read/write access to all accumulated objects, which allows analysts to work together on common arguments, as their time permits.

Since SEAS is meant to support a community of analysts, it must address issues of privacy and access. An analyst in the early stages of argument development might not want his or her work to be accessible by others. During development, an analyst might want certain individuals or groups to aid the process by reviewing or contributing to it. Even when an argument is complete, the analyst will want to control who will be allowed to see the results. Further, when an argument is used as evidence in support of another argument, then that argument serving as evidence must be guaranteed to persist in its current state to guarantee the integrity of the argument it supports. To address these issues of access control and stability of referenced objects, SEAS incorporates the concept of publishing. Three key attributes are related to the two states of publishing: unpublished and published. Published arguments and templates are guaranteed to persist, that is, they will continue to exist; no such guarantee is made for unpublished arguments or templates. As a consequence, only published arguments and templates can be reliably cited, much as only published works are (typically) included in bibliographies so that the reader has a real opportunity to obtain and read them. Unpublished arguments and templates are distinguished from published ones in that they are unstable, that is, likely to change in content. Published arguments and templates will not change. Finally, unpublished arguments and templates are distinguished from published ones in that their authors are given write access, while published ones restrict both their authors and audiences to read access.

All arguments and templates originate as unpublished works with a single author. While they remain unpublished, the author can add additional authors. Only the authors have access, and they are free to make modifications as they see fit. It is through this means that an analyst can enlist the help of other analysts in directly contributing to the development of an argument or template. An analyst can indirectly enlist the help of other analysts by linking arguments produced by them as evidence to support the argument, or by making use of templates developed by others as the basis for the arguments. Once a draft argument or template is ready for limited external review, the authors might add people or organizations to the audience. It is risky for this audience to link to this unpublished work since it might go away or be substantially changed in the future. When the authors decide that the argument is ready for external release, they publish it, giving read access to a specified audience in addition to themselves. These published arguments and templates can be reliably cited and referenced in other arguments since they are guaranteed to persist in an unchanging state.

Any author of an unpublished argument or template can change it at any time. In our most recent version of SEAS, the detailed history of changes is retained, allowing anyone with access to review the history of revisions. There is also a facility to spawn versions of an argument, that is, a copy of an argument in its current state, retained as a snapshot in its development. While the histories retain all the detailed changes, versioning provides a means to capture important waypoints in the development of an argument and, coupled with their graphical depictions, provides a convenient means to visualize the evolution of thinking, either by moving slowly from one depiction to the next or rapidly, producing an animation of its development.

While the ability for co-authors to make direct changes to a developing argument is essential, at times they would like to annotate an argument with issues, without changing the argument itself. *Memos* are structured annotations that are attached to objects within the SEAS knowledge base, including exhibits, evidence, discovery tools, questions/answers, arguments, and templates. Each memo includes text for its *subject* and *body* and a *type* selected from a preestablished set, including comment, critique, for review, to do, summary, instruction, and assumption. Like arguments and

templates, memos have a designated *audience* that restricts their access by others; only those who are members of the audience will know of their existence. One memo can be posted as a response to another, providing a means to imbed a threaded discussion regarding an element in an argument. As such, memos provide a means for private, semiprivate, or public discussion among analysts. Critiques are a way for contemporary analysts to contribute to each other's work. Assumptions might be added so that analysts in the future will better be able to interpret a historical analysis. Within SEAS, memos can be selectively filtered based upon their type, with graphical depictions indicating to the user where they can be found. This provides a ready means for analysts to find and interpret this form of meta-knowledge.

SEAS includes another collaborative capability to handle the situation where multiple analysts have each developed their own independent assessment of a given situation, each capturing his or her assessment in a distinct argument based upon a common template. Using starburst/constellation depictions of these arguments, one can quickly determine where there is agreement and disagreement in these assessments, but this does not directly lead to a consensus. To do so, SEAS includes a technique where a new argument is created, based upon the same template, with each primitive question supported by one body of evidence for each of the constituent arguments. Each such body of evidence captures how that analyst answered the question with the rationale he or she gave as the relevance. When this joint argument is produced, a fusion method and optional associated parameters are provided that are used to combine the disparate answers. That is, the fusion method (e.g., weighted average) and parameters (e.g., source credibility weights) are used to combine the collective answers for each primitive question to arrive at a consensus answer, and these, in turn, determine the consensus conclusions for all the derivative questions. The result is a single argument that captures all the independent opinions as supporting evidence for a single consensus opinion.

When deployed, we have seen the collaborative capabilities of SEAS used in different ways, according to locally established business rules. For example, in one case, a group at a U.S. intelligence facility wanted to make a joint assessment of a potential threat. The group's members established a multidimensional template to drive the assessment and created an argument, with all members of the team as co-authors. However, they broke up responsibilities for creating the assessment according to experience. The junior members were tasked with searching for potential evidence that they would attach to questions as exhibits; more experienced members were tasked to determine the relevance/irrelevance of those exhibits and to promote the relevant to evidence and to lower the signal flags on the irrelevant. Even more senior analysts would answer the questions based upon the collected evidence; the most senior member would review the overall result, using memos to identify problems that needed to be addressed. Although there is a linear progression implied in this division of labor, members of the team could work on their parts of the problem simultaneously. Coordination was achieved through signal flags and memos. However, it did suggest that SEAS might be enhanced to enforce such business rules, limiting the type of modifications that any analyst is allowed to make according to a specified plan of development.

In another case, SEAS was experimentally used to coordinate the collection and interpretation of information among first responders to a public health emergency. A template was developed that broke out the information and actions needed for a coordinated response among police, fire, hospitals, public health, and so on across city, county, state, and federal facilities. Upon a simulated discovery of a case of smallpox that could lead to an outbreak, an argument was established and made accessible over the Internet through a web portal. As various steps were taken (e.g., incident reported, communications established) and information acquired (e.g., identity and whereabouts of first and second contacts), entries were made in the argument, checking off accomplishments and attaching information. As such, the argument constituted a status board for the coordinated response, detailing the current situation status and highlighting what remained to be done.

In other applications, multiple templates have been used: some for coarse screening and others for detailed follow-up. For example, to address workers compensation fraud, one template was devel-

oped for use by store employees. It consisted of a very limited number of simple questions meant to quickly sort out likely legitimate claims from those that warrant further investigation. If this initial screening resulted in a red light, it was to be passed to professionals who would make a more detailed investigation. The initial argument would help the medical and legal professionals understand the reason for suspicion. They would then conduct an investigation, contributing their collective findings to a more detailed argument. Should a red light result from this more detailed analysis, it could be used as the basis for moving to litigation.

5. Evaluation of SEAS

SEAS has been subjected to testing, in a number of experiments, by a number of different organizations, applied to a number of different problems. In general, the results have always suggested that the form of structured argumentation implemented by SEAS shows promise; at the same time, there have always been suggestions for improvements, primarily focused on usability issues. We have attempted to build on the promise and make the improvements as resources have permitted.

In experiments conducted by DARPA (Defense Advanced Research Projects Agency), the ability of analysts to work counterterrorism problems was assessed, with and without the aid of new information technology tools [Popp & Poindexter 2006]. SEAS was one of the tools employed. The experiment broke the analytic problem down into three major steps broadly defined as research, analysis, and production. The results showed that analysts unaided by the tools spent far more time doing research and production than analysis; analysts aided by the tools were shown to reverse this, spending more time on analysis and less on research and production, allowing for more and better analysis in a shorter period of time. The significance is that analysts spend a greater percentage of their time doing what is most important, that is, critical thinking. The results also included an impressive savings in analyst labor and an increase in the number of reports produced—about half as many analysts created five times as many reports in the same amount of time. SEAS was credited with letting analysts explicitly represent their hypotheses for comparison and assessment, and identifying evidentiary data gaps for focused research.

The IRS (Internal Revenue Service) tested SEAS as a means to detect, classify, and quantify high-risk compliance patterns in tax filings from larger businesses [Lowrance & Ragoobeer 2004]. Some tax avoidance schemes use complexity to avoid detection and confuse IRS auditors, exploiting IRS stovepipes, cutting across multiple tax entities and multiple filing years. In this test, we worked with revenue agents on the analysis of a particular abusive tax avoidance shelter. A multidisciplinary team of IRS personnel was convened to analyze this current compliance issue and build an argument template for identifying its use. A prototype argument was later constructed for a particular case. Based upon this, the IRS concluded that SEAS has good potential to assist in systematically assessing compliance risk, enabling collaboration among IRS experts to move rapidly in identifying and analyzing complex schemes, providing access to evidence from multiple sources for multidisciplinary teams to weigh and agree on an appropriate response, and providing auditors with access to more current and comprehensive knowledge about related entities and potential compliance issues that affect the entity that they are assigned to examine.

Other evaluations resulted in the following statements:

- “The decision maker is able to access all information, consider the validity of the information and of the analyst, check the date of information to make well-informed decisions using all of the information that is available and ensure that the information is germane and current to the problem set at hand”
- "Currently...interactions between investigators, analysts, management and domain experts are ... telephone conversations, ...meetings, email correspondence etc. most of which is fragmented and lost over time. The SEAS system will provide a more convenient way to centralize this information and ...a record of ...our decision-making process"

- "SEAS, unlike many point-solution analysis tools, supports an extended analysis process with functions for problem formulation, information gathering, evidence handling, evidence assessment, and forming final conclusions. Overall, the analysts found the process clear and had no difficulty adapting to it."

While we firmly believe that structured argumentation and collective reasoning, as implemented by SEAS, has a significant role to play in the general areas of collective evidential reasoning, it is by no means a complete solution. Many aspects of the general problem require different approaches and supporting tools. Search engines, transaction analysis tools, natural language extraction and translation tools, teleconferencing environments, link analysis tools, timeline analysis tools and statistical analysis tools, along with the more mundane email, instant messaging, spreadsheets, word processing, and presentation development tools, all have a role to play. In addition, other approaches to structured reasoning need to be supported. SEAS is applicable when there is a given hypothesis that can be decomposed into its constituent elements, and that decomposition can be exploited to guide the finding and interpretation of evidence, to arrive at a conclusion regarding the validity of that hypothesis. In some situations, no hypothesis or too many hypotheses exist for this approach to be practical. Instead, hypotheses need to emerge as coherences in the available evidence are discovered [Pioch & Evertt, 2006, Rodriguez, Boyce, Lowrance, & Yeh, 2006].

6. Relevance to legal reasoning

We are just beginning to investigate the applicability of SEAS to problems in legal reasoning. While SEAS looks to have something to offer in this context, it also looks like some modifications would ease its application in this context.

The first application suggested to us was to use SEAS templates to capture the definitions of claims and affirmative defenses, defined in terms of their essential elements. For example, the essential elements of a negligence claim might be (1) duty of care, (2) breach of duty of care, (3) injury caused by breach, and (4) proximate cause; the essential elements of a waiver defense to an otherwise valid negligence claim might include (1) a voluntary and (2) knowing (3) surrender (4) in writing of (5) a legal claim or potential legal claim (6) in exchange for legal consideration (Tillers). Here the claim/defense could be captured as the root node in a unidimensional template, directly supported by nodes representing each of the essential elements. For a claim, the light scale could range from green, the complete satisfaction of a legal requirement, to red, the complete dissatisfaction; for an affirmative defense, we might reverse the scale so that green always corresponds to a claim being upheld and red to it not. As such, these templates capture the generic elements of legal rules.

Given that there are a limited number of affirmative defenses that might be used to invalidate a given claim, the unidimensional templates for these defenses might be brought together with the unidimensional template for the claim, to form a multidimensional template. As such, this multidimensional template would capture all of the rules of law that are (potentially) at play with respect to a given claim. By retaining a library of such templates within SEAS, and indexing them according to the nature of the claims, the results from queries against this library for each claim that is included in a case, would remind a lawyer of all of the applicable rules of law and supporting essential elements. Each relevant template could be used to establish an argument pertaining to each claim; this collection of arguments would then be used to guide the establishment of the facts in issue and the evidence supporting/refuting those facts. SEAS already includes facilities for forming and graphically viewing such collections.

Essential elements in the rule of law are abstract; they do not pertain to specific people and events; they need to be grounded in the specific factual hypotheses that are ultimately in issue. Therefore, the next step, after instantiating SEAS arguments based upon the relevant templates, is to instantiate generic legal requirements (e.g., "negligence") with specific spatio-temporal events (e.g., "Employer removed a safety guard rail on June 1, 2001, from the milling machinery at his plant in

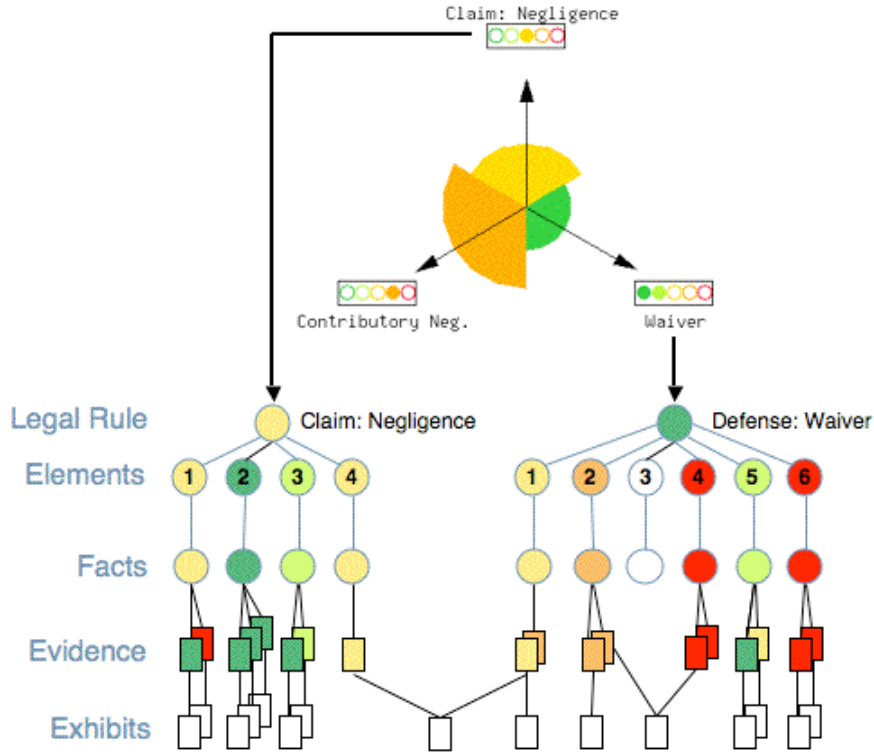


Figure 8: A depiction of a claim and affirmative defenses from legal rules to evidence

Mills, Ohio”) that constitute the facts in issue. This might best be captured in SEAS as arguments consisting of exactly one question i.e., whether a fact in issue is true/false. These could then be cascaded under the appropriate essential elements; should a fact in issue pertain to multiple essential elements, the corresponding argument could be cascaded under multiple elements. In turn, evidence would be sought for each argument pertaining to a fact in issue. Multiple pieces of evidence would frequently be associated with a given fact in issue; each would support the truth or falsity of that fact to varying degrees; an estimate of the credibility of each source of the evidence would be used when calculating the conclusiveness of the evidence; a single document (i.e., a SEAS exhibit) might serve as evidence for multiple essential elements.

Figure 8 is a depiction of a case involving a negligence claim. At the top of the figure is a starburst that summarizes the state of the case, including a claim of negligence along with a waiver and a contributory negligence defense. The yellow light associated with the claim indicates that it is only marginally satisfying the rule of law, while the green light associated with the waiver defense indicates that it is unsatisfied, but the contributory negligence defense is mostly satisfied, i.e., across the claim and defenses, green corresponds to the claim being upheld and red to it being rejected. So from just this starburst, it can be seen that, at this juncture, the affirmative defense is ahead of the claim. If the case included multiple claims, then arraying multiple starbursts in a single display, one pertaining to each claim, would provide a concise summary of the overall status of the case.

Below the starburst in Figure 8 are depictions of the arguments corresponding to the claim and the waiver defense (the contributory negligence defense is not depicted to conserve space). These consist of a root node corresponding to the rule of law with nodes immediately below them corresponding to their essential elements (the elements are the same as those discussed in the second paragraph of this section). Here it can be seen that the second element of the claim is satisfied, the third is mostly satisfied, while the first and fourth are only marginally satisfied. Since all the ele-

ments of the claim must be satisfied for the claim to be upheld, the weakest elements (first and fourth) drive the conclusion for the claim (i.e., it is only marginally satisfied). Examining the argument corresponding to the waiver defense reveals that it is not currently a threat to the claim, driven by its third element being unsatisfied.

Below each essential element is a fact in issue that instantiates that element. These are single-question arguments. Each of these is connected to the evidence that relates to it and each body of evidence is connected to its supporting exhibit. Assuming that automated fusion methods are employed to fuse the evidence under each fact in issue, as new evidence is added, the degree to which the facts in issue are substantiated would vary, as would the degrees to which the essential elements are satisfied. In turn, this would determine the degrees to which the claims and defenses are satisfied. Utilizing the various ways to view arguments in SEAS, one should be able to quickly see what aspects of a case remain to be addressed, and which are problematic. To the extent that a case is being assembled by a team, the collaborative features of SEAS could be used to coordinate their efforts.

7. Conclusions

The structured argumentation methodology and SEAS were developed to aid those performing analytic tasks. In particular, we were not looking to automate the analytical reasoning that they perform, but to facilitate it. This methodology

- Encourages careful analysis, by reminding the analyst of the full spectrum of indicators to be considered
- Eases argument comprehension and communication by allowing multiple visualizations of the data at different levels of abstraction, while still allowing the analyst or decision maker to "drill down" along the component lines of reasoning to discover the detailed basis and rationale of others' arguments
- Invites and facilitates argument comparison by framing arguments within common structures

Today, intelligence analysts usually capture their knowledge in text documents. Typically, these documents have minimal structure, limited to section titles that break up the document. These intelligence reports are intended for human consumption. However, because of their limited structure they are time consuming to read and understand. To compare one report with another requires that both reports be read, and it is up to the reader to find common and uncommon aspects of the underlying reasoning. It is also up to the reader to extract the analytic method if it is to be employed in doing related analyses. Searching a collection of such reports to find ones that might be related to the current problem of interest is also time consuming. Of course, word processing and search engines can help to speed this process, but the level of aid is fundamentally limited.

We believe that our structured argumentation methodology, as implemented in SEAS, has shown that the addition of even minimal structure into the analytic process can aid analysts in developing, communicating, explaining, and comparing analytic results. An important aspect of this methodology is the retention of direct links to the source material and its interpretation relative to the conclusions drawn, allowing analysts to readily comprehend the thinking of others. This, coupled with a collaborative environment and a corporate memory of previously developed templates and arguments, allows analysts to leverage the thinking of others both past and present. Finally, even though our methodology was originally motivated by the desire to help intelligence analysts, it has been shown to be applicable to other domains of application. While we have yet to show it, we believe that it could be usefully employed to support legal reasoning.

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