

Characterizing the intelligence analysis process through a longitudinal field study: Implications for visual analytics

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Abstract

While intelligence analysis has been a primary target domain for visual analytics system development, relatively little user and task analysis has been conducted within this area. Our research community's understanding of the work processes and practices of intelligence analysts is not deep enough to adequately address their needs. Without a better understanding of the analysts and their problems, we cannot build visual analytics systems that integrate well with their work processes and truly provide benefit to them. In order to close this knowledge gap, we conducted a longitudinal, observational field study of intelligence analysts in training within the intelligence program at Mercyhurst College. We observed three teams of analysts, each working on an intelligence problem for a 10-week period. Based on the findings of the study, we describe and characterize processes and methods of intelligence analysis that we observed, make clarifications regarding the processes and practices, and suggest design implications for visual analytics systems for intelligence analysis.

Keywords

Intelligence analysis, visual analytics, qualitative user study

Introduction

Visual analytics applies to many domains and problem areas, but one area of particular study since the beginning of the field has been intelligence analysis. Intelligence analysis is a cognitively demanding process, one that seems ideal for the application of visual analytics tools. Accordingly, a growing number of systems have been built for it.^{1–4}

Research in human–computer interaction also teaches us to deeply analyze and understand end users and their problems in order to design appropriate computational solutions. We question whether visual analytics systems, including some of our own, have been based on a deep enough understanding of the discipline. Relatively few studies of intelligence analysts, their tasks, and their work processes exist. Notable exceptions^{5–8} provide initial insights into the field, but we have frequently interacted with analysts who feel

that their practices are misunderstood and that visual analytics systems often fail to address their most important problems.

To address these concerns and to learn more about the analysis process, we conducted a longitudinal, observational field study of intelligence analysis on real-world problems. Unfortunately, getting access to working professional analysts is challenging. Even if they are available, it is difficult or impossible to study them for an extended period of time while they work on real tasks without having some type of special

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access that simply was not available to us. As an alternative, we studied analysts in training who are soon to become working professionals. More specifically, we studied groups of students from the Department of Intelligence Studies at Mercyhurst College as they conducted a long-term intelligence project.

We were given deep access to the students, the materials they examined, the tools they used, and their final intelligence products. We interviewed the teams multiple times and observed their group meetings. Additionally, we interviewed their instructor to learn his impressions of the process. Our goal was simply to better understand what these young analysts do, the challenges they face, and how we might be able to help them. Thus, the contributions of our research include a characterization of the processes and methods of intelligence analysis that we observed, clarification and reflection of several beliefs about intelligence analysis processes and practices, and resultant design implications for visual analytics systems for intelligence analysis.

Munzner⁹ has argued of the importance and the need for more domain characterization research like this. She notes that such research is both difficult and time-consuming to do properly, but the visualization community could benefit greatly from it.

This article is an extended version of the conference paper.¹⁰ We have added an expanded discussion of the tools and methods used by the analysts with a specific focus on their use of wikis. We discovered that wikis were used pervasively by the analysts for a variety of benefits. We explain how the analysts used wikis and the specific characteristics of wikis that assisted the analysis.

Background

One of the most widely used models in the visual analytics community is Pirolli and Card's⁷ sensemaking model for intelligence analysis. While the model broadly characterizes processes used in the analysis activities and has guided the design of visual analytics tools, the model does not provide rich details of how intelligence analysts work in the real world. More empirical and descriptive explanations of the intelligence analysis process are required to provide appropriate visual analytics system solutions.

Several studies have captured and characterized the work practices and analytical processes of individual or collaborative analysis through a qualitative approach. Chin et al.⁵ conducted an observational case study with professional intelligence analysts in which participants worked on real-world scenarios. The researchers revealed various characteristics of the analytical processes of intelligence analysts. Gotz et al.¹¹ also recognized the lack of studies examining analyst behavior

and conducted a user study to explore the ways in which analysts gather and process information. Another study by Robinson⁸ examined how analysts synthesize visual analytics results by studying domain experts conducting a simulated synthesis task using analytical artifacts. Based on the analysis of video coding results, he identified several characteristics in the process of collaborative synthesis. While these studies did not evaluate specific visual analytics tools or features per se, they provide valuable implications to inform design directions for future support tools.

Relatively few studies examine the analytical culture in general. These include a number of books^{6,12-14} published from the intelligence analysis domain. These books provide insights into the complex analytical process as seen by those who practice it as well as an understanding of some critical aspects of the analysis.

Krizan,¹² in *Intelligence Essentials for Everyone*, provides a slightly revised version of the traditional intelligence cycle,¹⁵ which contains several component functions including intelligence needs, collection activities, processing of collected information, and analysis and production. Quoting Dearth,¹⁶ she states, "These labels, and the illustration below, should not be interpreted to mean that intelligence is a uni-dimensional and unidirectional process. In fact, 'the process is multidimensional, multi-directional, and—most importantly—interactive and iterative.'"

Clark¹³ also describes the current intelligence process using his target-centric approach to intelligence analysis. Examining how intelligence should be done, he advocates an inclusive approach that includes all the stakeholders or individuals affected by the intelligence produced. In this approach, he argues that "the goal is to construct a shared picture of the target, from which all participants can extract the elements they need to do their jobs and to which all can contribute from their resources or knowledge." Compared to other models, this approach implies more interactivity throughout the analysis cycle.

Johnston,⁶ an anthropologist, conducted an ethnographic study of the Central Intelligence Agency (CIA) for a year and identified variables that affect intelligence analysis and requirements for techniques and procedures to reduce analytical error. While he made useful recommendations to improve analytical performance, his approach was primarily intended to understand organizational culture and describe current community practices, rather than identifying leverage points for designing support systems.

While many researchers have suggested new intelligence models and tried to emphasize nonlinearity, existing intelligence process models still do not clearly and accurately describe what people do in intelligence analysis and fail to capture the nuance of the process

as practiced. In our study, we aim at an in-depth exploration of the intelligence analysis process, emphasizing the disconnect between theory and real-world practice. We also seek to deeply understand the analysis process with an eye toward designers, so that we can provide meaningful implications for developing technological support for analysts.

Methods

In order to investigate the intelligence analysis process in-depth, we conducted an observational study of teams of analysts conducting an in-class intelligence project. In the long-term (10-week) project, each team addressed a real intelligence problem proposed by a client. We observed three teams, monitoring their status and process throughout the project. At the end of the project, each team had to produce final deliverables and present their findings and analysis to decision makers.

Participants

We recruited three groups of students, one team of four undergraduate students (Team A) and two teams of five graduate students (Teams B and C), from the Department of Intelligence Studies at Mercyhurst College.¹⁷ Mercyhurst's Intelligence Program, started in 1992, provides education for students who want to pursue a career as an intelligence analyst. It is recognized as one of the top programs for intelligence studies in the United States, offering a broad range of classes and degrees for students seeking a career as an analyst in national security, law enforcement, or the private sector.

We recruited students who were taking the courses named "Strategic Intelligence" (undergraduate) and "Managing Strategic Intelligence" (graduate), in which teams are required to conduct an analysis project over a 10-week term. The two courses are very similar with respect to the projects. The students all were close to graduation, with past internship experience, and most of them had already received job offers.

While these student teams clearly are not practicing professional analysts, there was not a significant difference between the way the students worked and the way real analysts work, according to the instructor. The analysis process used in the class was modeled directly after the process employed by the US National Intelligence Council to produce its strategic reports, the National Intelligence Estimates.¹⁸ The instructor also intentionally stayed relatively detached from the students, acting as a mentor and limiting his supervision, so that the teams could autonomously work on the project. The teams were diverse in expertise on the subject matter, which is common for teams in the

intelligence community (IC). One key difference from real-world practice was the relative absence of administrative and bureaucratic overhead affecting the student teams, as well as issues relating to security clearances. They operated in a much more "sanitary" environment than the real world.

Task

Different types of intelligence questions exist—we focused on one of the most common types, strategic intelligence. Strategic intelligence is "intelligence that is required for the formulation of strategy, policy, and military plans and operations at national and theater levels."¹⁹ In other words, strategic intelligence is the intelligence necessary to create and implement a strategy, typically a grand strategy. It aims to provide ways to accommodate and/or coordinate a variety of variables. Strategic intelligence is exploratory and long term in nature.

The requirement for tasks within the class was that "the questions should be relevant and relatively important to the client's success or failure but outside their control." We served as a client/decision maker for Team A in order to observe the process even closer, whereas Teams B and C worked with external organizations. The specific issues each team addressed were the following.

Team A. The strategic assessment of potentially influential factors to the evolution of computer-mediated undergraduate and graduate distance education: What aspects of computer-mediated distance education will likely influence R1 institutions during the next 5, 10, and 20 years with specific, but not exclusive, emphasis on undergraduate education and computer science? As part of this overreaching question, this study will seek to address key components including:

- Enrollment figures
- Value of education
- Cost of education

Team B. Who are the key people, technologies, and organizations that likely currently have or will develop the potential to disrupt or replace traditional US national security IC analytical workflows and products with commercially available products available over the next 24 months? Criteria that will be used to identify these key players are as follows:

Those who are not beholden to the IC or US Government as primary sources of funding.
Those who have the potential to solve IC-like analytical problems.

Those who are looking at future-based events or actions that are outside the control of the forecaster/predictor.

Those who are focused on forecasting or predicting future courses of action.

Team C. What are the most consistent and identifiable characteristics displayed by potential insider threats to (a defense department)?

- An insider threat will be defined as an individual or collection of individuals employed directly or indirectly by the department who violate security or access control policies with the intent of causing significant damage to the department's personnel, operations, or information.
- Within the broad range of insider threats, special priority will be given to violent threats and improper diversion of information or physical assets.
 - Violent threats include actions that endanger department personnel, physical assets, and the department's protective service mission.
 - Improper diversion includes the sale, surrender, and/or sabotage of information or physical assets.

Throughout the study, we tried to minimize our intervention, and, furthermore, every decision on the intelligence process (e.g. what tools to use) was made by the study participants. The teams updated the status and the process of the project on a wiki site. At the end of the semester, they needed to produce a final report that synthesized analytical results and strategies of the entire analysis process.

Study protocol and procedures

The analyst teams conducted the project for 10 weeks—from the week of 1 September through the week of 10 November 2010 for Team A and from the week of 1 December to the week of 14 February 2011 for Teams B and C. Normally, strategic intelligence projects range from a couple of months to years; 10 weeks is short but within normal limits for strategic intelligence.

Before the project began, the external clients formulated a draft of their initial intelligence problem. In the first week of the project, the clients conducted a conference call with the analyst team to discuss the scope and requirements of the problem. During the next 2 weeks, the analysts refined the problem and wrote a formal statement of the intelligence question, which they call "Terms of Reference (TOR)." Upon approval from the decision makers, the teams began working on the problem, which took another 7 weeks.

The wiki platform was used as a workspace for analysts to document their process and findings, and we were able to monitor the wiki's status throughout the project period. The final reports of the projects were also documented on the wikis.

During the project period, we conducted two face-to-face meetings with each team—one in week 7 and the other in week 10. In the meetings, we interviewed each team as a group and the class instructor in order to learn more details about the project's status, process, difficulties, and future steps. Each interview took approximately an hour. While the interview was semi-structured, we followed an interview guide containing several key topics,^{20,21} including the following:

- How do the analysts perceive their analysis process?
- What barriers and difficulties do they encounter?
- Tools and aids being used—where and why?
- Collaborative aspects in the analysis process.
- Where in the process can technology help?

We also observed two team meetings firsthand, which took about 3 h in total.

Data collection and analysis

Most of the process descriptions and produced artifacts were stored digitally. The teams reported methodologies, tools used, sources, as well as the findings on their own website (wiki). To further understand the process, we analyzed interview notes and audio recordings from the focus group interviews. We used the artifacts produced by the analysts, such as drawings, wiki pages, tables, and slides, as further data. Additionally, we had access to history logs of wiki page changes.

We transcribed each interview's audio recording and then coded the transcripts based on the grounded theory approach.²² We began by identifying major themes and categories from the text. One emergent theme focused on the analysis process, including methodology and challenges encountered. Another theme was collaboration, focusing on how and to what degree the analysts collaborated and what types of collaboration existed. Throughout the coding process, we iteratively refined the categories. We then elaborated on supporting evidence from the data for each category through a deductive approach.

Results and findings

Overall analysis process

Through the project, we found that four component processes were essential to the overall analysis:

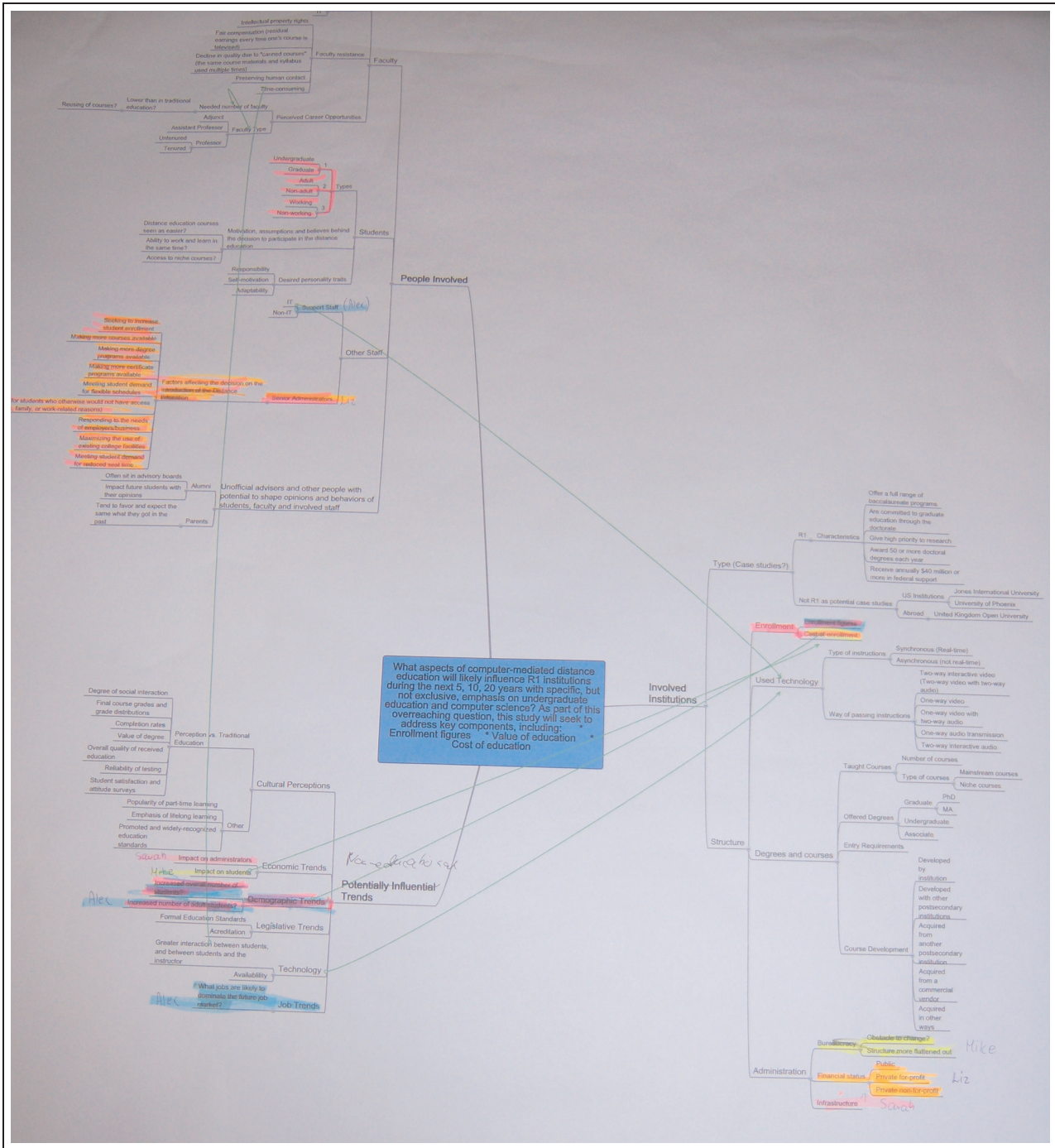


Figure 1. A conceptual model.
Source: Printed from Mindmeister.²³

constructing a conceptual model, collection, analysis, and production. While the four processes did not occur linearly, this section describes the importance of each and how the analyst teams worked on each.

Phase 1: constructing a conceptual model. Once the teams and clients/decision makers finalized the requirements of the intelligence question, the teams

started to build a conceptual model, which is a map of issues and concepts that the team will be investigating to address the problem. The conceptual model illustrates the areas the analysts need to research by helping them to visualize the question at hand. The question is placed in the center and then several high-level components of the question surround the question (Figure 1). Each component branches out and

creates a bigger map, from which the team gains an idea of the areas with less/more information that they need to research. This allows the team to focus on collecting a set of data with an appropriate scope.

While the significance of the conceptual model differs depending on the question and the team, it plays a key role for the team to understand the domain area and determine the direction of research. We were told that analysts often construct this conceptual model implicitly, rather than externalizing it, which we found quite interesting. The instructor commented:

In most cases, it's implicit. People don't write it down. But it's the way they are actually doing it. There's a model in people's heads, and that's far more important than the data. There's research that says analysts' judgments are far more driven by the way they think about the problem than the data itself. So making the way you think about the problem explicit would allow analysts to identify whether they disagree about how to think about this model, and to merge their best thinking about this model. So the process happens, it's just the degree of to which it's made explicit, that is unusual.

Phase 2: collection. While working on the conceptual model, the teams also assigned areas/concepts to each member. Next, they collected information from various sources including online and offline sources (e.g. interviews with experts), which they call “all-source intelligence.” While each analyst was responsible for collecting data about their assigned topic(s), the team shared their sources using Zotero,²⁴ a web browser plug-in for gathering and organizing source material. This allowed teammates to view the data like a common library—other team members might already have found information that they need. More specifically, the data collection process typically involved these steps:

- Once an analyst identifies needed information, they search the Internet using search engines and various keywords.
- The analyst also sets up Rich Site Summary (RSS) news feeds on websites of interest using Google Reader.
- Whenever they find useful sources, whether for their own topic or someone else's, the analysts place the link into a Zotero group library.

The collection process occurred from the very beginning to the final stages—the ninth week of the project.

Phase 3: analysis. The analysis phase exhibited various characteristics depending on the requirements and analytical methods used. In this phase, analysts

processed data that they collected from many different sources in order to convert “information to knowledge.” While Team A directly began writing short format analytical reports on each topic, Teams B and C used a more structured format (e.g. spreadsheets) to quantify information and rank the significance of each topic or entity. No matter which method they used, the initial analysis of each topic/entity was undertaken and written by one person in accordance with the assigned topic. However, everyone on the team could review and comment on others' work via the wiki pages. In all cases, the analysis phase was incorporated with the collection and the production phases.

Phase 4: production. Once individual collection and analysis were almost finished, the teams met and tried to synthesize findings from each part, which led to the “key findings”—the major product of the analysis. Production was an intensive reading/writing process in which the team collaborated tightly with each other. This stage was more to prepare a presentation for the decision makers. Team members repeatedly checked their sources and findings to make sure that they were consistent and logical.

Reiterating, while we separated these four components for the sake of clarification, the process was not simple, and it was not clear which phase the team was in throughout the project. Instead, the characteristics of the question and the analytical method chosen most influenced the process. In our study, we observed two different styles of intelligence analysis process. The difference in approaches resulted from the type of the intelligence question.

Intuitive analysis—Team A. Team A addressed potentially influential factors to online distance education in the near future. Because the requirements were rather broad and intuitive, the team decided to take a top-down approach, investigating meta-information sources such as research that forecasts future education trends.

Instead of using a specific analytical method, this team depended considerably on the conceptual model and used it as a guide throughout the entire project. They put significant time and effort into constructing it, revising the conceptual model until the seventh week of the project. Because of time constraints, they were not able to cover all the topics in the model. Through discussions, they chose a number of concepts they felt most worth exploring and divided up the concepts for each member.

After collecting and reading information for their designated topic, each analyst wrote a short format analytical report that synthesized the information.

MCIM : Entities								
Entity Name	Unstructured Data	Unreliable Data	Incomplete Data	Detect Deception in Data	Data Extracted	Application Compatibility	Impact Score* (see Impact Matrix)	Total Score
Text Analytics	3	0	3	1	3	3	3	16
Dependency or Association Analysis	0	2	2	2	0	3	3	12
Network Analysis	0	2	2	2	0	3	3	12
Data profiling and transformations	2	2	1	2	0	3	1	11
Prescriptive Analytics	0	2	1	2	0	3	3	11
Sequential Pattern Analysis	2	0	2	0	2	3	2	11
Bayesian Analytics	0	2	0	2	0	3	3	10
Clustering or Segmentation	0	2	0	2	0	3	2	9
Optimization Models	0	1	1	1	0	3	3	9
Game theory	0	1	1	0	0	3	3	8
Regression Analysis	0	0	0	2	0	3	3	8
Basket Analysis	0	0	2	0	0	3	2	7
Classification	0	0	0	1	0	3	3	7
Simulations	0	0	1	0	0	2	3	6
Time series forecasting	0	0	0	0	0	3	3	6
Time series tracking	0	0	0	0	0	2	2	4
Behavior Learning Software-Machine Learning	3	2	3	2	3	3	3	19
Neural Networking	3	2	3	3	3	2	2	18
Complex Event Processing	3	2	2	3	2	2	2	16
Statistical Package for the Social Sciences (SPSS)	3	1	2	2	2	3	3	16
Temporal Analytics	3	1	3	1	3	3	2	16
Reality Mining	3	1	3	1	1	3	3	15

Figure 2. MCIM of people, technologies, and companies. MCIM: multicriteria intelligence matrix.

Most of the analysis simply involved reading. For a few topics that required careful weighing of alternative explanations, the team employed analysis of competing hypothesis (ACH).¹⁴ While documenting results, everyone was able to review and edit others’ drafts on the wiki page, and team members frequently discussed others’ analysis (short write-ups) both online and face-to-face. Therefore, everyone was responsible for the reporting of each topic.

After working on the individual topics, the team met to write key findings together. This team invested considerable efforts in synthesizing their findings because their narrative was extremely important for their intuitive type of analysis.

Structured analysis—Teams B and C. Teams B and C used structured analysis with quantified information because their research questions tended to be more specific and required rank ordering of entities (e.g. top x indicators, key people/companies). Both teams built their conceptual model in the beginning as a base model. For these teams, however, the model was more of a collection plan rather than an actual conceptual model. Although they used the model to collect information and divide up the work, they did not refer to it

for the remainder of the project. Instead, they started building a matrix in a spreadsheet to collect and analyze data from diverse sources. The matrix was rather a reinterpretation of the conceptual model, and each cell in the matrix indicated a collection requirement.

The purpose of the matrix was to evaluate each entity based on the criteria chosen and to identify the most influential ones, those of most interest to the decision maker. Team B, which was asked to identify key people, technologies, and companies that might affect IC products, created a matrix and chose criteria while collecting information (Figure 2). They identified 180 entities and graded each based on the criteria, noting the ones with highest scores. Team C, which was asked to identify indicators displayed by potential insider threats to a defense department, analyzed data from the 117 case studies about crimes using a matrix (Figure 3). They used it to compare the relationship between crimes and motivations, as well as crimes and indicators.

In both the teams, the matrix captured the conceptual model and how each team was thinking about the question. Filling in the cells was a time-consuming part as analysts needed to read and analyze each

Categories of Crimes	Number of Indicators Per Crime	Number of Indicators/Person	Personal									
			Isolationist Personality	Inflated Self Image	Mental Health Issues / Disorders	Suicidal tendencies	Hopellessness	Survivalist Mentality	Strict / Absent parents	Excessive interest in	Perce	Perce
Homicide	26	9	5	6	9	4	1	0	2	4	7	
Murder	26	9	3	2	5	4	1	0	0	4	4	
Nidal Malik Hasan	17	4	1	0	0	1	0	0	0	1	0	
John Russell	15	5	0	0	1	1	0	0	0	0	1	
Hasan Akbar	15	4	1	1	1	0	0	0	0	0	1	
William Kreutzer	14	6	1	1	1	1	0	0	0	1	0	
Dean Mellberg	8	4	0	0	1	0	0	0	0	1	1	
Dr. Bruce E. Ivins	10	6	0	0	1	1	1	0	0	1	1	
Espionage	24	7	2	3	3	0	0	0	2	0	2	
Espionage	17	6	1	1	2	0	0	0	0	0	1	
Brian Patrick Regan	4	2	0	0	1	0	0	0	0	0	0	
Timothy Steven Smith	5	2	0	0	1	0	0	0	0	0	0	
Ana Belen Montes	1	1	1	0	0	0	0	0	0	0	0	
Ariel Weinmann	6	1	0	0	0	0	0	0	0	0	1	
Robert Chaegun Kim	2	1	0	0	0	0	0	0	0	0	0	
Kurt G Lessenthien	2	1	0	0	0	0	0	0	0	0	0	

Figure 3. Case study matrix of crimes.

case/source to fill in one cell, addressing “the devil in the details.”

However, this type of analysis required additional efforts in the production phase. Initially, the teams converted qualitative information from sources into quantitative information for rank ordering. Once they had completed the matrix, the teams needed to transform its data into a story, so that it could be made useful to decision makers.

Upon the completion of the projects, the instructor evaluated the teams’ performances as being in the “top 10% of the projects over 8 years.” He commented that all three teams performed the analysis well, and in one case, the decision maker briefed the head of his organization with the team’s results.

Tools and methods used

The teams used various software tools and analytical methods to develop hypotheses, arrive at analytical estimates, and create written reports and multimedia products.

Wikispaces/Google Sites. The teams used a wiki platform (Teams A and B—Wikispaces, Team C—Google Sites) to exchange gathered information, aid administration, and share organizational details. The wiki sites became part of the final product, displaying the key findings, TOR, and all analytical reports.

Mindmeister (conceptual model). Mindmeister²³ is an online mind-mapping tool the teams used to build a conceptual model. A conceptual model provides a revisable platform to view the requirements and their components. As research and facts begin to support or refute initial ideas, main ideas become more solidified and focused.

Zotero. The teams used Zotero²⁴ as a source collection database. Downloaded as an Add-on to Mozilla Firefox, Zotero allows the analyst to search websites and save the sites in a database that is accessible through the Zotero website. The teams used the group library feature to place their sources in a single database.

Website evaluation worksheet. To evaluate the credibility of the online sources, all the teams used the Dax Norman Trust Scale.²⁵ This matrix allows scores to be applied based on the criteria such as clear bias, corroboration of information, and the analyst’s overall perception of the source. Based on the sum of scores, the source can score a high, moderate, low, or not credible rating.

Decision matrix. A decision matrix is a decision-support tool allowing decision makers to address a problem by evaluating, rating, and comparing

different alternatives on multiple criteria. Teams B and C employed a modified version of a decision matrix appropriate to address their problems.

Analytical confidence. Each report includes an analytical confidence section that conveys to the decision maker the overall doubt connected with the estimative statement(s). While assessing the level of analytical confidence, the teams used Peterson's²⁶ method. Peterson identified seven factors that influence analytical confidence: the use of structured analytical methods, overall source reliability, source corroboration, level of expertise on subject, amount of collaboration, task complexity, and time pressure. In the analytical confidence section, the teams addressed these six factors as applicable to the particular estimate.

Social network analysis. Team C employed social network analysis using i2's Analyst's Notebook² to see relationships within the industry. The team analyzed the social network analysis based on betweenness and eigenvector scores.

ACHs. Team A used ACH for some problems. ACH is a simple model for assessing alternatives to a complex problem. It takes analysts through a process for making a well-reasoned, analytical judgment. ACH is particularly useful for issues that require careful weighing of alternative explanations of what has happened, is happening, or is likely to happen. It also helps analysts minimize some of the cognitive limitations.

Wiki usage in intelligence analysis

Since wikis were extensively used as a workspace for analysts in our study, we further examined their wiki usage throughout the process. In addition to the three wikis we observed in the study, we also examined five other wikis as a reference. This section details how and to what extent wikis were used in their intelligence process.

Wiki statistics. We looked at the usage statistics from Wikispaces and Google Sites to better understand the context of the work. Because Google Sites does not support the number of page views, only statistics from the two teams are considered for "the number of views."

Number of pages of analysis. For the teams, 37, 111, and 48 wiki pages were created, respectively. Each wiki page is counted as only one page no matter how long it is. When printed, however, each wiki page

can be several pages in length. This number represents the number of pages in the finished projects and not the total number of pages created. In our study, some of the pages—approximately 37%—were created to help write the projects and then deleted in the final cleanup before presentation to a decision maker.

Number of files uploaded. A total of 81, 202, and 152 files were uploaded and used for the analysis. The files include images, Excel spreadsheets, charts, and Word documents.

Number of edits. While an "edit" can be fixing a spelling error or rewriting an entire wiki page, the number of edits can be a useful measure of how much contribution the analysts have made. In our study, the teams generated 1638, 2650, and 1655 edits or an average of 425 edits per analyst. If we look at the number by page, 30 edits were made for each page on average.

Number of views. Whenever an analyst clicks on a page, whether it is read or not, it counts as a view. Analysts, as a normal part of the analytical process, often examined and commented upon the work of others in their group. The analysts generated 14,665 and 21,524 page views or approximately 4021 page views per analyst. Each page on average was viewed 228 times by the analysts.

How analysts used wikis. As shown in the statistics, the analysts heavily used a wiki for the project. The teams' purpose for using the wikis was interesting as well.

In the projects we observed, the use of wiki sites started from the very beginning of the project. Once the teams met with clients and clarified the questions and requirements, they set up their own wiki site and uploaded TOR to a page. In this stage, the teams also invited clients to the wiki, so that the teams could communicate with their clients more effectively. Throughout the process, the teams used the discussion feature available in the wikis, enabling communication between analysts about specific tasks and the overall project.

In the early stages of a project, a wiki was primarily a repository for information. When the teams were actually working on a conceptual model, they used another tool (i.e. Mindmeister) and had more face-to-face meetings for discussion. Once they created an initial conceptual model, they put the model into the wiki (Figure 4). As the project evolved, the model helped analysts identify intelligence gaps, discover new information, and update current information, thus aiding in the evolution of the project. Wikis, therefore, helped

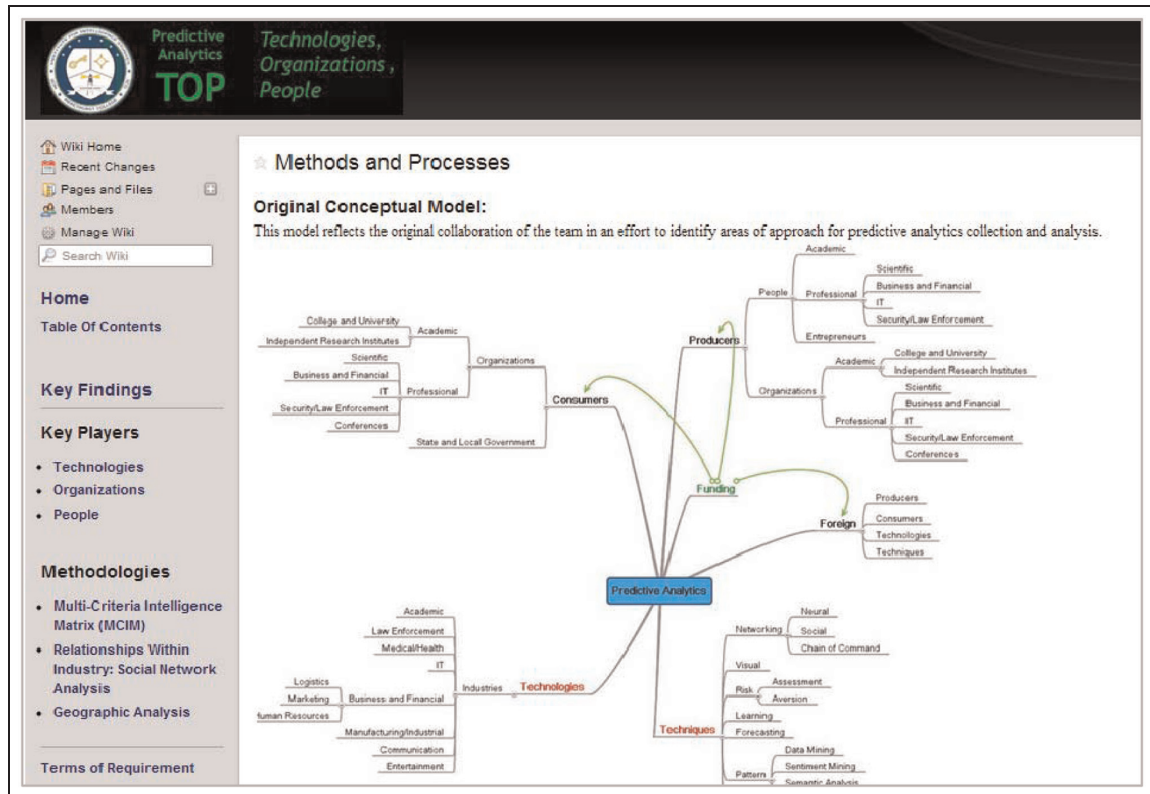


Figure 4. A conceptual model added to a wiki.

the team members stay familiar with the conceptual model throughout the project period.

Once the teams decided what to collect based on the conceptual model and started collection, the wiki served as a platform for rapid gathering of information from different sources. Although the teams used more sophisticated tools such as Zotero or Google spreadsheets for the majority of the collection effort, they still uploaded a selected number of highly useful resources to the wikis. Because wikis preserve information and make it easily findable with a simple search function, they seemed to be a good repository for resources. For most of the resources, analysts referenced the sources by hyperlinking to outside or internal sources, which is easily supported by wikis.

While the teams were collecting information, analysts started working on the analysis part. For intuitive analysis, a wiki was the main workspace for the analysis. Analysts created pages for their assigned topics and directly started writing into the pages. In the analysis phase, wikis provided transparency to both the teams and the clients. While working on their own pages, analysts could review others' work—each contribution and each modification in the process. Although a wiki alone did not lead to specific insights or findings, it was a medium for a better collaborative output. For structured analysis, the analysts primarily worked on

Excel spreadsheets because they had to create matrices and fill out each cell. The analytical gains derived from using wikis were relatively small.

The production phase is all about wrapping up the project and putting on final touches to create a polished product. All the teams extensively used wikis in the production phase because they chose a wiki platform as a final deliverable. We observed many structural changes at the end of the project. Teams reorganized numerous pages they created, merged or deleted pages, and modified links to make the wiki easier to navigate without significant changes in the content. Because wikis are flexible and can easily adapt when requirements change or analysts prefer a different structure, wikis seemed to be ideal for production. Analysts also did a lot of formatting and editing on the wiki to polish the output.

Finally, the teams were able to create a final report on the wiki platform, documenting all of the analysis process, methods, resources, and key findings. Since a well-organized wiki format helped clients navigate the output, the teams created a table of contents for more effective navigation (Figure 5).

Wiki example: "National Intelligence Estimate". As mentioned earlier, we examined wikis that had been

Table of Contents	
<ul style="list-style-type: none"> Home Terms of Reference ▼ Key Findings <ul style="list-style-type: none"> ▶ Crimes Versus Indicators ▶ Crimes Versus Motivations Fermi Estimation Case Study Matrix Cases Studied Additional Readings Methodologies Contact Information 	<h2>Table of Contents</h2> <ul style="list-style-type: none"> I. Terms of Reference II. Key Findings <ul style="list-style-type: none"> 1. Crimes Versus Indicators <ul style="list-style-type: none"> a. Unhappiness/Disgruntled with Work Environment b. Perceived Extreme Stress c. Disregard for Workplace Rules d. Poor Performance/Received Reprimands e. Mental Health Issues/Disorders f. Isolationist Personality g. Aggressive/Disagreeable Social Disposition h. Job Instability i. Failure to Establish/Maintain Intimate Relationships j. Unsuccessful Social Acceptance

Figure 5. Table of contents created for clients to navigate.

created in the past class projects in addition to the three wikis used in the projects we observed. To better illustrate how analysts organized the wikis and what kind of contents they put into the pages, we provide a detailed example of a wiki used for a “National Intelligence Estimate on infectious and chronic disease.” While the wiki was created 5 years ago, it still has about 350 unique visitors per day (as of 22 February 2012).

In the project, a team of 26 graduate student analysts collaboratively worked on estimating important impacts/threats to US national interests resulting from infectious and chronic disease originating outside the United States over the next 10–15 years. The home page of the wiki contains a short description of the project, a navigational tutorial including a video, and special features such as terms and icons for readers to better understand the reports (Figure 6).

In the left pane, the default top menu has general actions related to the wiki such as “Pages and Files” and “Recent Changes,” as well as the search box. The navigation pane on the bottom left lists important pages that the clients and other potential readers should visit, including “Home,” “Terms of Reference,” “Final Estimates,” “National Interest Matrix,” “Methods and Process,” “Resources,” and “Contact Information.”

- In Terms of Reference, readers can find the key estimative question and secondary estimative questions of the projects, which define the scope of the analysis in detail.
- The Final Estimates page (Figure 7) contains the answer to the Key Estimative Question at the global, regional, national interest, and country levels.

Each estimate page contains detailed explanation including an executive summary and discussion, ranging from one to five pages. The Global Estimate Video is also included in this page.

- National Interest Matrix is a page where the team embedded a matrix created in Excel spreadsheet. The matrix quantifies the impact of disease on US interests in each country and region round the world on a 5-point scale. As the team took a structured analysis approach, this matrix gives a good overview of how the team derived the Final Estimates.
- The Methods and Process page provides background information detailing the analytical processes that the team followed. It describes how the team developed the project to best answer the Key Estimative and Secondary Questions, allowing readers to understand the team’s approach and procedures throughout the project period.
- The Resources page is a library of the works collected by the team throughout the project, including reports, journal articles, books, websites, and videos. The resources are also organized by geographic regions, so that readers can easily look up to the references.
- Finally, Contact Information lists all 26 analysts’ email addresses and their roles in this project, so that readers could contact them with relevant questions and comments.

All the pages are connected through hyperlinks, allowing easy navigation between the pages. This particular wiki would have been over 1000 pages if it were a paper document. Using the wiki, the team seems to have effectively organized the contents of the report,

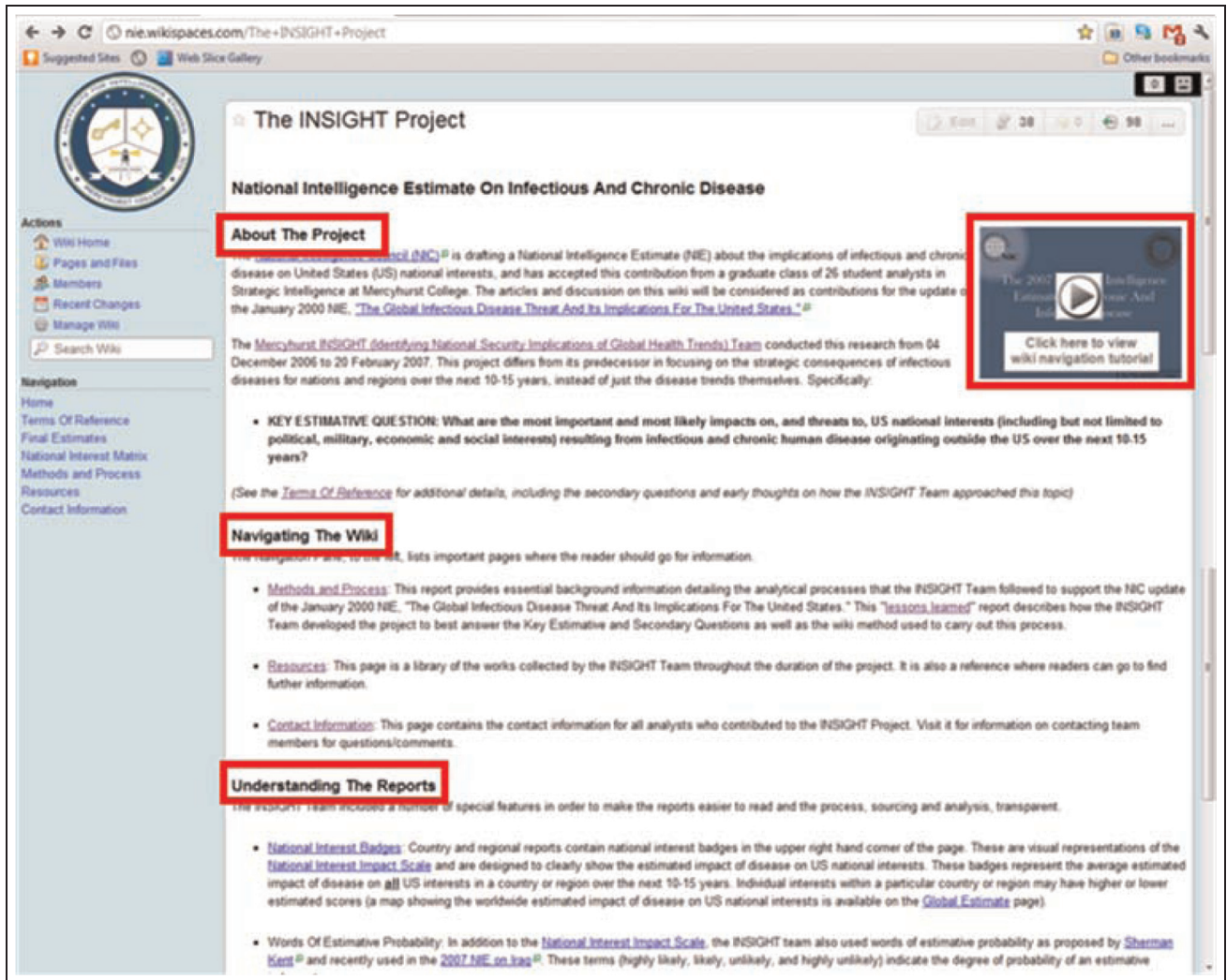


Figure 6. Home page containing “About the project,” “Navigating the wiki,” and “Understanding the reports.”

so that readers can access the information they need more easily.

Understanding the intelligence analysis process

Observing analyst teams helped us to better understand their goals and processes. In particular, the study highlighted a number of misconceptions we harbored about the intelligence process. Other visual analytics researchers may or may not share these preconceived beliefs, but we think that they have the potential for misunderstanding and are thus worth exploring.

Intelligence analysis is about finding an answer to a problem via a sequential process

Some existing models of the intelligence analysis view it as an answer-finding process with a sequential flow,

as noted in several models of the intelligence analysis process.^{12,15,27} This perception presumes that the process is linear, sequential, and discrete by step. Pirolli and Card’s⁷ sensemaking model includes the notion of iterations and revisions between steps, but the fundamental assumption is that separate stages exist throughout the process and that analysts transition between stages.

However, this model was not the intelligence process we observed. Instead, the process appeared to be more parallel and organic, as one analyst described:

Intelligence analysis is not about getting from point A to point B along the route, but it is better associated with basic research where you don’t necessarily know where you are going to go. You’re cutting a path through the jungle that’s never been explored. That’s what you’re doing in most intelligence analysis projects. It’s not a mechanical process in a sense that an assembly line is. It’s

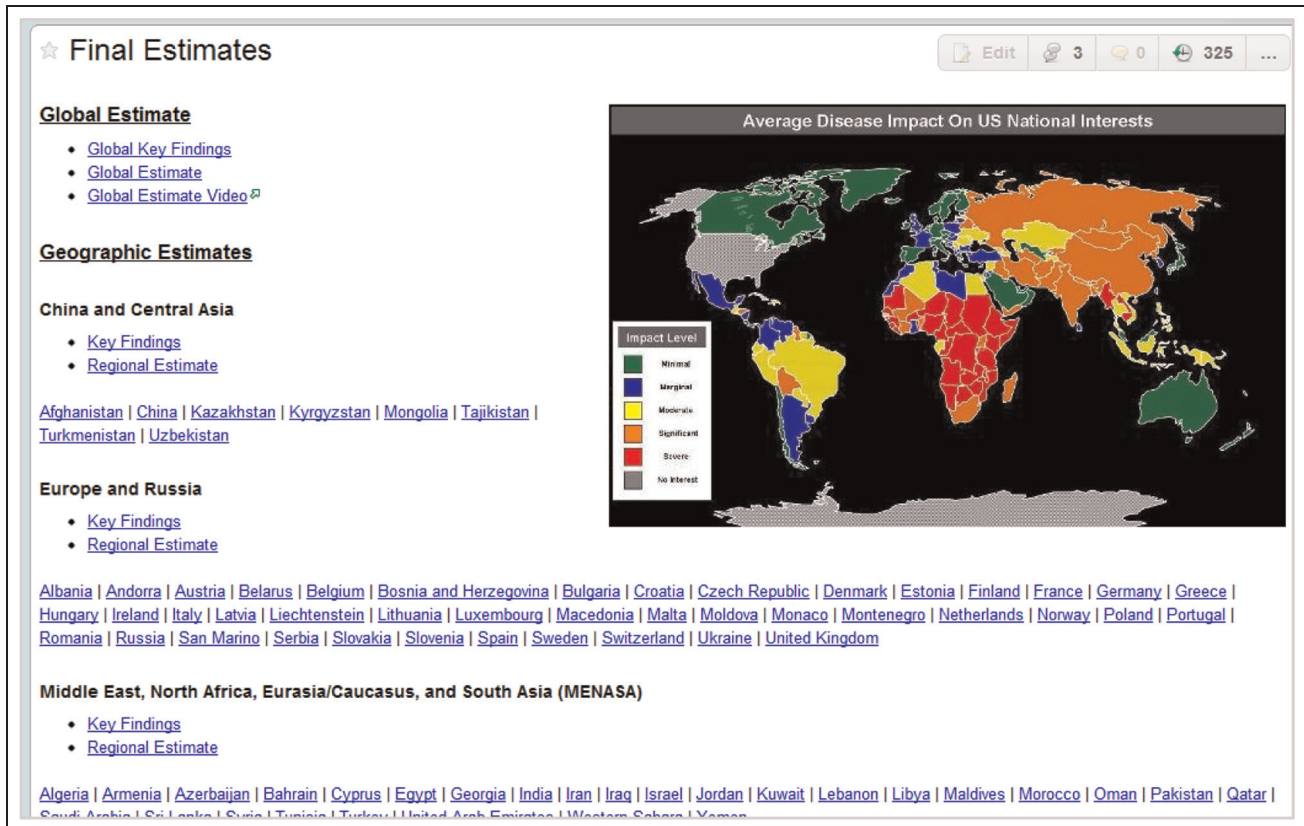


Figure 7. Final Estimates at the global, regional, and country level.

a very exploratory activity by nature. You have to expect that some of the stuff you do, some of the things you think, you have to be willing to discard them. Because at the end, they will be rarely relevant, or you find something better that contradicts to it, and that's just the nature of it.

The key part of the intelligence process is the analysis of a specific set of data

Visual analytics systems often manipulate preprocessed data for the analysis. A primary misconception about intelligence analysis is that the data analysis process, in which investigators analyze a set of collected data, is the most difficult part and takes the most time. This belief assumes that the analysis occurs after investigators collect all data required for the analysis.

This view, however, needs to be changed. Although analysis is important, we observed that the process of “constructing a frame,” as described in the data–frame theory,²⁸ is more important. In other words, intelligence is about determining how to answer a question, what to research, what to collect, and what criteria to use. This process becomes part of the analysis—

analysis implicitly occurs during the process of the construction. Analysts also explore different sets of analytical techniques to address a problem. Deciding which method to use is important, but it often changes during analysis as the way that analysts think about the problem evolves, depending on information that constantly flows in.

Understanding that collection and analysis are integrated together in the process of building a frame is extremely important. Systems are not likely to be successful in supporting intelligence without acknowledging that fact. One analyst commented:

Intell analysis is not like that you have a set of data in hand and run a program. It's like a conundrum from the very beginning. You have to learn how to learn, how to frame the question, and how to answer it through collecting and evaluating sources.

Analysts do not often collaborate

One common perception of intelligence views analysts as isolated individuals who prefer to work alone, struggling with pieces of information, rather than as

collaborative teams.⁵ However, a faculty member at Mercyhurst countered this perception:

Collaboration is almost all intelligence analysts have done in the context of the team. In the CIA or DIA, working as a team is pretty normal. While working on a particular topic within an agency is typical, also typical is working on an interagency team that consists of analysts from different agencies such as state department teams, DIA teams, and NSA teams.

Analysts are normally organized by function or geographical region. These typically operate as loose teams. Strategic projects almost always involve a team as do crisis projects (for example I am sure there are multiple Libya teams that did not exist a month ago). In short, teamwork is the norm although the teams differ in the degree of formality and to the degree that there is a designated leader.

During our study, we also observed many collaborative elements of intelligence analysis. Collaboration is commonplace in intelligence analysis, and understanding how that occurs is important because it influences one's whole notion of the process. The IC itself has recognized the importance of improved collaboration since 9-11.²⁹ Although collaborative tools have been built and they are pushing users into tighter collaboration, it is still important to understand where tighter collaboration will be beneficial and where it may not help much.

We found that multiple layers of collaboration exist in intelligence analysis and that the degree of collaboration differs depending on the type of task and the group dynamics. We observed that analysts usually do not collaborate tightly on data and content—the actual collection and analysis. Although the teams had meetings frequently—twice or three times per week—the main purpose was to discuss their status, issues, and the next steps, as two analysts said:

We come up with an agenda before meeting, a list of what we're supposed to talk about—what we did, what we want to do, what the questions we need to solve as a group. We didn't really plan that way, but it just happened. It's the way it is.

There was no detailed, content-based work during the meeting although sometimes we had discussions on controversial issues. We basically do work in our own time, get preliminary ideas of it, and get together and discuss what issues we had.

The teams often worked together in the same laboratory, but it was rare that they worked on the same document or content. They worked on their own part, but they often talked to each other about issues and questions. Essentially, they took advantage of being in the same place at the same time. To better

support analysts' work, we need to understand the collaborative aspects of the intelligence process and where technology can leverage collaboration. Some tasks are inherently done better by an individual.

We can help intelligence analysts by developing sophisticated analytical tools that assist their thinking process

Visual analytics researchers often seek to help intelligence analysts by developing technologically advanced analytical tools, thereby assisting their cognitive processes. The tools support specific types of analysis, specific analytical methods, and specific stages of the process. Such tools certainly can be helpful, especially to assist analysts to handle a flood of information.

However, our study revealed that analysts want something more than that. Currently, more than 50 analytical methods exist in the IC,³⁰ and analysts try many different kinds of techniques depending on the problem. Consequently, their dependency on a specific analytical technique is relatively low. Instead, the ability to manage the intelligence process effectively and employ various analytical methods and tools quickly is more important, as the instructor and an analyst said:

Everything is fragmented. I've got Mindmeister here, Mindmeister doesn't interface with my search technology and Google reader. I've got to manually go out and figure out what all those bullets are. No help from a computer ... But there isn't any set that ties all these, the pieces are there, Mindmeister, Zotero, RSS Google reader, MSWord, the wiki, are here, but nothing links all that in one seamless thing so I can go from the requirement to a product in a single package, in a single way.

Doesn't need to be perfect at all. Needs to be able to jump back and forth and if somebody says to me, "Oh no, your product due tomorrow!" I've got to be able to take whatever system. I'm only in 2/3 of the process and I've got to be able to jump to the end of process and write the final report, get it done by tomorrow. That's the way intelligence works.

If the processes of collection and analysis are integrated in a single system, this helps analysts apply structured analytical methods such as ACH, social network analysis, geospatial mapping, and decision matrix. In our interviews, two teams mentioned that if they had more time, they would have tried other analytical techniques. Analysts always want to push their findings and triage, aggressively reshuffling their analysis. One of the most effective ways to do this is to employ multiple analytical methods and compare and contrast findings from each. The ability to try various techniques with the data can help analysts find effective ways for addressing questions and strengthening their analysis.

Rethinking the intelligence analysis process

Linear versus parallel

One might believe that the way intelligence analysts work is quite simple and straightforward. First, they specify requirements, build a conceptual model of what to research, then collect information, analyze data using various techniques, and finally write a report. This belief is a common misconception about intelligence as mentioned in the previous section. The reality is quite different. Rather than working linearly, analysts work on *everything* during almost the entire project. That is, analysts do not hold writing until enough information is collected; they keep revising analysis and writing as new information flows in. Analysts do not decide what to research and move on to collecting information; they start searching for information even when they are not sure what to research. Analysts do not produce final products after they are done with analysis; they already have an idea or a structure of final products in the very beginning, although it may be rough.

This “parallelism” is portrayed well in Wheaton’s model of the intelligence process (Figure 8). In each phase, one of the core processes is emphasized most but all other functions operate in parallel. Wheaton³¹ argues that “All four functions begin almost immediately, but through the course of the project, the amount of time spent focused on each function will change, with each function dominating the overall process at some point.”

Although several distinct elements exist in the analysis process, all are very closely coupled and the connection is very organic. One can easily observe an analyst working on collecting new information while analyzing and checking the credibility of previously collected sources at the same time. In our study, we observed that a team’s conceptual model changed drastically in the middle of the process, that a new

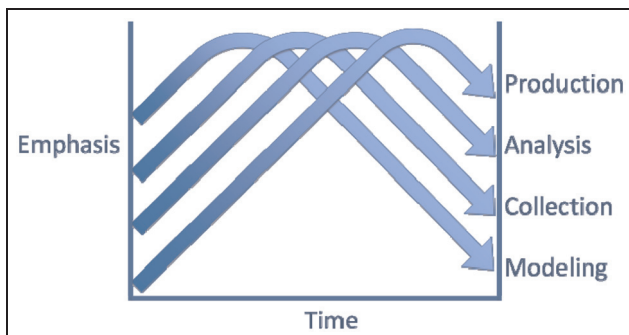


Figure 8. Wheaton’s multiphasic model of the intelligence process.²⁸

information source was added 10 days before the deadline, and that a previous analysis report was discarded and new analysis began at a later stage. The matrices also kept changing as new information arrived. While the teams were working on the matrix, they were collecting information at the same time to make sure that they were familiar with the area. Several quotes better explain this:

But it isn’t as rigidly isolated as it’s on that (traditional) cycle because you can’t build a good conceptual model without knowing what’s out there. So there’s little bit of collection as you’re building the model and we refined it.

Our conceptual model is changing. It doesn’t get set in phase 1 and we drive it, that’s the difference between this process and an outline. An outline drives your production. But we are using it differently. As it changes, we’re changing our analytic focus, we’re making decisions about production, who’s going to write something, who’s going to do the analysis, based on how it’s changing and that’s being informed by new information that comes in.

It’s the most updated version. There’s never final. We are constantly revising as we go along. You get to the point where it’s ready to be in the final report, but then if you get new information that contradicts that, then that paper either has to be drastically edited or has to be thrown out entirely.

Pirolli and Card’s sensemaking model

How does this new way of thinking about the intelligence process relate to Pirolli and Card’s⁷ sensemaking model? Because it is the most widely used model in the visual analytics domain, we were curious about how well their model explains real-world intelligence analysis processes.

Pirolli and Card’s model provides new insights into the intelligence process, suggests leverage points for analysis tools, and has guided the design of many visual analytics systems. However, we argue that the model still implies sequential, discrete stages of the intelligence process although it acknowledges that analysts can move either top-down or bottom-up or jump to different stages. For example, the model does not explain why analysts so frequently jump from one state to another state that is not adjacent. Many visual analytics tools thus support specific states only (e.g. shoebox and evidence file, evidence marshaling, and foraging), and often they do not blend into the entire process of intelligence analysis.

More importantly, the model describes how information transforms and how data flow, rather than how analysts work and how they transition. It gives a very insightful illustration of how the form of information

evolves from raw data to reportable results. However, it does not quite fit analysts' mental model of their work process because they do not work as information is transformed. Rather, information is transformed by how analysts proceed. Similarly, all different states of the model can exist at any point during the process. Analysts may have polished reports on certain sub-topics, drafts of analysis, structured matrices, and a collection of documents at a time.

The Pirolli-Card model identified various leverage points for visual analytics tools, but the linearity of the model could give researchers an inaccurate impression of the process. While models are inherently abstract and stage based, it is important to understand the context and the purpose of the model. We would characterize their model as more of an information-processing process rather than intelligence analysis process. Pirolli-Card explicitly state that the model was suggested as a starting point to investigate the domain. While it has contributed to visual analytics researchers understanding of the domain, now we need to change our assumptions to build systems that better help intelligence analysts with their work.

Where and how collaboration occurred

Collaboration throughout the process

Throughout the project, the teams worked tightly together although the degree to which they collaborated differed depending on the phase of analysis. Once the project started, the team set up weekly meetings. The first thing they had to decide was to specify requirements of the problem and then they collaboratively worked on building the conceptual model. Whether the team kept using this model or changed to a matrix, it played a role as a representation of their "group thinking," as an analyst described:

You want to say that this is the way I'm thinking about this problem. These are some of things I need to think about. And what we've done by building the conceptual model is to have that sort of group interaction, which is not necessarily harmonious action. There can be disagreements about how we should be thinking about this. And if there's shifting, moving it around, that represents an evolution of the way of our thinking.

Once the team had an idea of the areas to explore, they divided up the work and assigned concepts to each analyst. While each one worked on different concepts, they collaborated in collecting information by using a group library. Although this seems to be loose collaboration, the benefit the team gained was invaluable because it could significantly save time and effort

in collection. An analyst explained how they worked in collection using Zotero:

Zotero is a good example of one way we collaborate. Each person creates a group library on the Zotero server. If I find a website that I think is useful, whether for my topic or someone else's topic, I add it to our group collection, and then other members can see it before they go searching the Internet for something. And if she doesn't find that in Zotero, then she might go out Google. So ... try Zotero first, you might already have it.

While working on and analyzing their own topics, team members often met with each other to check status and discuss issues. When not all team members were available, they used typewith.me,³² a web-based collaboration tool for writing. When most of the areas they had planned to explore were covered and analyzed, they collectively wrote the key findings—the crux of the analysis project. Very tight collaboration occurred in this work. They met together and spent significant time to synthesize findings from all the topics and write the key findings.

Sharing versus content versus function

We found that three different types of collaboration exist when analysts discuss the topic: sharing, content, and function.

Sharing is a way to collaborate by sharing information. In our study, analysts shared sources to better assist their search process and understanding of the topics. At a higher level, however, this can be the sharing of analytical products as well as information sources. When people mention the importance of collaboration in the IC, they primarily refer to the sharing of information sources and analytical results.³³ This type of collaboration can be significantly supported by technology.

Collaboration also occurs at the *content* level. This type of collaboration, in which analysts work together to create analytical products, can be seen more often in a small-sized team. Examples in this project include constructing a conceptual model together, dividing concepts and assigning to each analyst, commenting on each other's analysis, working on ACH together, and writing the key findings together. However, in our study, once work was divided, then each part was done individually. The degree of tightness in this type of collaboration may directly affect the quality of analysis. The more closely the team works together, the more that output is coherent and logical. However, in reality, it is difficult to collaborate on content because of efficiency. This type of collaboration is also difficult to facilitate via technology because so many subtle

issues—such as social dynamics, politics, teamwork, and motivations—are involved.

Functional collaboration is needed to execute practical tasks for completing the project, such as editing, creating a matrix structure, specialized analysis on a specific topic, and polishing deliverables. While analysts work on the same thing and divide up the analytical product in the content level, functional collaboration naturally emerges at the later stage of the process as the team begins to think about allocating multiple functions. In this type of collaboration, analysts reinforce their strength. For example, if one is a good editor and has a detailed eye, then that person would do the editing, as one analyst explained:

There was a lot of collaboration. A spent a lot of time working on wiki stuff. B spent time doing the ACH stuff. C did a lot of technical stuff. So each of us spent extra amount of time doing something specific. Whichever parts of this you want to take on, those are the parts that get divided up. As different as I do this (analysis), I do this concept, I do this concept.

Olson et al.³⁴ similarly characterized collaborative activities of groups by analyzing design meetings from four software teams. Focusing on the time spent in meeting activities, they found similar patterns across design teams. In meetings, teams spent 40% of the time in direct discussions of design, 30% of meeting time was spent taking stock of their progress, and coordination activities consumed approximately 20% of the time. Clarification of ideas across these activities took one-third of the time, indicating that participants spent a large amount of time sharing and explaining expertise.

How wikis facilitated the analysis process

Previously, we described how analysts used wikis throughout the analysis. While wikis do not seem to provide analytical support per se, we examined how wikis assist the analysis process more broadly. The instructor commented that he had observed projects over several years and teams were more productive when they adopted the wiki as early as possible. What characteristics of wikis helped the process and offered productivity gains?

Low initial barriers, easy to use, and compatible

The primary reason that the analysts liked to use wikis is that they are easy to use and work well with other software. Analysts are often pressed for time. While a number of sophisticated systems exist, analysts do not

have plenty of time to learn about and get familiar with a system. If a system has a high learning curve, the chances are rare it will be adopted by analysts. Analysis also occurs across several tools. Results and information snippets often need to be integrated into a single system, and wikis seem to do a reasonable job in embedding outputs from other applications such as YouTube videos or Google docs. In our study, the teams noted:

We chose Wikispaces as our preferred wiki platform because it is relatively easy to use and it works well with various external applications. For example, it allows for the embedding of YouTube videos or Google Documents. It is easy for new users to learn rules that allow for the basic editing of pages. More advanced users can use the text editor which is part of the wiki, or the widget function called “Other Code” to change or add code in order to add additional sophisticated functionality to wiki pages.

Even though wikis have relatively low initial barriers, analysts who are not familiar with such applications would have adoption issues and stick to traditional approaches. Once they overcome the initial barrier, however, the productivity gains seem to be significant, as shown in the following quote:

When they choose to continue more traditional style work flow, that has everything to do with the adoption problems—classic problems in wikis. Two factors that are important in that are “how easy is wiki to use” and “how reliable it is.” Once analysts overcome the problems and adopt it early, the productivity gains are huge.

All-in-one-place nature, from requirements to production

The analyst teams used the wiki platform as a main tool throughout the entire project—from requirements to production. In the beginning, the wiki served as a structural, organizational space for the remaining analysis. Then it became a living document for work in progress, ultimately resulting in a final deliverable. Although the analysts employed other tools at some point when they needed a specific analytical functionality, the wiki stayed as the major place of their work.

This all-in-one-place nature allowed the analysts to shift their attention easily between the four functions (phases) of the process. By capturing most of the process up to date, the wiki serves as an effective platform for starting collection efforts, analyses, and even finished products.

The ability to support production seemed to be attractive to both analysts and decision makers. They

can export the wiki as a printable format such as pdf and use either an electronic or a printed version of the product.

Focus on the process as well as the result

Since the team members (and possibly decision makers) consistently reviewed and monitored the wiki pages throughout the project, they were able to focus on details in every stage of the process. That is, wikis reflect the reality of the intelligence process, allowing the teams to focus on the process as well as the result of the intelligence.³⁵ This is the particular advantage the wikis provided compared to other systems.

Transparency in process

Wikis provide transparency in the analysis process. For example, everyone can access the history of edits including edits on pages, files, and tags. Being able to see the history of edits increases accountability for the analysis process. The instructor commented on this feature:

This team made about 2,000 edits so far. Go and find, and take a look at how many edits were made in the key findings section. I like to watch the history of important documents like key findings. You can look at the initial version, you can look at the middle version, you can look at the final version, and you can watch the evolution of changes, much as same as Wikipedia. Same kind of thing happens here. An important document gets seen or edited a lot; you can actually watch the team think. That's pretty cool.

Editors and readers are often interested in the history of edits and like to compare the changes made, particularly for important pages, similarly as done for Wikipedia.

Platform for asynchronous, calm collaboration

A single analyst working on a project without colleagues may see little benefit in using a wiki, other than the fact that it is accessible anywhere. However, as described in the previous sections, almost all analytical processes are collaborative among many people.

The benefit of wikis is maximized when the team size is relatively large. Most of the analyst teams we studied had about four or five members, which might have been manageable without wikis. Still, the teams told us that wikis were very effective for collaboration by making the collaboration status—who is working on what and how much progress has been made—visible.

Wikis also encouraged discussion and communication of ideas and questions among analysts. Since

analysis should be objective and incorporate different perspectives, these collaborative features of wikis helped the analysts accommodate varying viewpoints. In addition, wikis allowed each individual to easily review and edit others' work. This peer-review process provided an opportunity for analysts to challenge assumptions, double-check sources, and identify areas that need further research. Ultimately, with repetitive peer reviews to the same article, the bias and inaccuracies could be minimized. One analyst commented about this collaborative support of wikis:

Wikis don't make me faster, they make us faster.

Flexibility in structure: easy to reorient anything

It is hard to structure a site without knowing its contents and flow. Since analysis is an ongoing process and requirements and collection needs often change, analysts cannot predict and arbitrarily create pages in wikis. That is, the table of contents and organization of pages keep changing until the very end of the analysis.

Wikis have a very important characteristic that can help with this matter; they provide the analyst teams with enormous flexibility. Using traditional approaches, it is quite difficult and cumbersome to reorient everything, but wikis support this very efficiently.

Analysts in our study often changed the structure of the wiki pages, even at the end of the process, but they did not find it difficult. Because all the information and writings the team had created were stored as separate pages by topics, it was relatively easy for them to add/remove, change structures, and modify links. The flexibility inherent in the wiki seemed to allow for easy reorganization of the pages.

How wikis are used for collaboration—domain comparisons

While a handful of research publications have investigated wikis and their usage, an article by Fuchs-Kittowski and Köhler³⁵ provides a good explanation of why wikis are good at cooperative knowledge creation and exchange. He argues,

With the help of a wiki, users can easily gather and integrate knowledge into the existing (wiki) knowledge base by the user. The particular advantage of the wiki approach compared to other cooperative knowledge generation and exchange systems is the focus on the *process* as well as the *result* of communication.

For example, content and document management systems tend to focus on the exchange of results of tasks

done by several people. Discussion boards, in contrast, focus mostly on the cooperation process, making the exchange of opinions possible. The results of the discussion are generally implicit in the individual postings and have to be abstracted afterward. Wikis, in contrast, allow users to discuss and work on the result simultaneously. That is, cooperative production of content becomes very efficient through “the realignment of the distinction between author and reader.” This characteristic, also discussed in the previous section, significantly benefited the intelligence analysis process in our study. Intelligence analysis consists of knowledge-intensive tasks and work processes and is characterized by nonlinear sequences and dynamic social interaction. A wiki is an appropriate interface in that it supports the knowledge creation processes.

Many researchers have explored how wikis are used for collaboration, especially in corporate settings. These studies^{36–40} reported that wiki technology was used to support a wide range of work activities within a corporation, including team collaboration, project management, information dissemination within communities of practice, idea generation, project planning, and e-learning.

The focus of previous research studies regarding wikis has been adoption and sustainability. For example, a survey of 168 wiki users conducted across diverse firms indicated that corporate wikis were sustainable “based on the length of wiki existence, the number of participants, the number of lurkers, and the frequency of accesses.”³⁹ In the research, authors identified three types of benefits achieved through the participation and use of corporate wikis: “benefits to enhanced reputation, benefits to making work easier, and benefits to helping an organization to improve its processes.” They argue that benefits are more likely perceived when work tasks require novel solutions (rather than routine tasks) and when other wiki contributors are believed to provide credible information. While our study was not conducted in a corporate setting, it seems that the characteristics of the tasks our analysts conducted and the tight group dynamics were quite suitable to wikis and helped analysts perform the work. Their study also identified three groups of wiki contributors—adders (who add pages and content), synthesizers (who integrate, reorganize, and rewrite whole paragraphs), and commenters (who comment and make small corrections). We found this classification interesting and somewhat congruent with our study results. In the previous section, we discussed that some members spent more time in practical tasks such as editing and reorganizing—synthesizers. However, we did not see a clear distinction between the three groups of contributors in our study since all members actively participated in adding pages and content and

commenting on each other’s work. We assume that this might be because of a small group size, where the level of contribution is even more transparent. In Arazy et al.’s³⁶ study, respondents also rated highly the direct benefit of wikis in supporting their work and enhancing their productivity, and the benefit seemed to be correlated with their level of proficiency in using wikis.

Phuwanartnurak⁴¹ describes a field study of two interdisciplinary design teams, seeking to discover how wikis support information sharing in software development projects in a university information technology (IT) department. The study provides evidence that a wiki is simple and easy—all members from both software development teams liked the wiki because it is easy to use. Our study also proved that analysts favored low initial barriers and easy-to-use features of wikis. He also reports that wikis encouraged more information sharing among team members during the software development process and made the work more visible to other disciplinary groups, which were apparent in our study. His study had interdisciplinary teams, and he observed that roles and tasks have a lot of influence on how design team members would use a project wiki. Although we did not examine that aspect specifically, this will be worth exploring for future research.

Egli and Sommerlad⁴² report the experiences of a law firm with adopting wikis for knowledge management and collaboration over 2 years. They describe that wikis created a business advantage for the lawyers through better reuse of their know-how within the firm, and external wikis for clients created new revenue opportunities and higher client satisfaction. They divide their internal wikis into three groups—collaboration wikis (used for internal purposes only), information-display wikis (open to clients), and personal wikis (initial wikis that are not yet developed into a collaboration wiki). In our study, analysts used a wiki as a workplace for collaboration and also as a final deliverable for the clients, which means that the entire process of analysis was transparent to the clients. This difference seems to be due to the characteristics of the work and the degree of confidentiality. As the advantages of wikis, Egli and Sommerlad point out the easy establishment of new instances and the level of speed and flexibility and emphasize how wikis can be made useful as a collaboration tool, as shown in the quote:

The real power of Wiki is fully revealed as a collaboration tool. By sharing your thoughts with others you enable them to develop their own ideas starting not from scratch but from a certain level. Their thoughts then again help you to have new ideas. The result of this mutual feedback process is more than the sum of all single ideas. It’s something new that couldn’t have been created without Wiki.

As already mentioned this does not only work within a team but also when you use it for our very own purposes. An idea you had as a 35 year old person might be looked at from a very different angle at the age of 45.

The study also identifies the disadvantages of wikis, one of which being the lack of a task management tool and schedule. It is crucial when using the system as a workflow management tool, that is, a system administering a legal file's documents as well as the related tasks and deadlines.

The use of wikis to support distributed collaborative writing has been also investigated.⁴³⁻⁴⁵ Chi et al.⁴⁵ developed Dandelion, a tool that extends wikis to support coordinated, collaborative authoring. Through real-world pilot trials, they found that the system was especially useful in structured, collaborative authoring situations with designated coordinators, where the role of a coordinator is clear and the document outline is relatively known. For free-formed collaborative authoring, Dandelion added little on to a standard wiki.

Several studies focused on challenges in the adoption and use of wikis.^{46,47} Holtzblatt et al.⁴⁶ explored factors that impacted the use of wikis within a corporate environment and discovered two major factors that contributed to staff's unwillingness to share information on a wiki—(1) a reluctance to share specific information due to a perceived extra cost, the nature of the information, the desire to share only finished content, and sensitivities to the openness of the sharing environment and (2) a heavy reliance on other non-wiki tools based on work practice, lack of guidelines, and cultural sensitivities. Grudin and Poole⁴⁷ explored where, how, and why people use wikis at work, focusing on the creation and use of wikis on corporate intranets in scientific and engineering organizations. They identified challenges in adoption and long-term sustainability of wikis, which include (1) mismatch between management visions and the benefits delivered by successful wikis, (2) limitations of current wiki-based tools that impact long-term use such as the difficulty of reorganizing information, (3) the disruption of bringing another technology for communication and information sharing into environments with established practices, and (4) unfamiliarity with the collaboration model inherent in wikis, including uncertainties about accountability. The authors conclude that wikis may be most successful in supporting newly established groups or short-term activities.

How visual analytics can help: design implications

How can visual analytics help intelligence analysis? Based on our study findings and reflections, we

suggest several design implications for systems supporting intelligence analysis.

Externalize the thinking process—help analysts continuously build a conceptual model

Good analytic practices encourage continuous improvement upon the conceptual model throughout research, which continues through the end of the project.

The analysts in our study told us that the process of making sense of a problem and building a conceptual structure is one of the most important parts of intelligence analysis as it decides the direction of analysis. In most cases, analysts encounter a situation in which they need to learn about new subject matter, but it takes time and effort until they become familiar with the domain. Because they cannot build a good mental model of the problem without knowing what information is available, they struggle to know more about the domain until the later stage of analysis.

Using the power of representation, visual analytics systems can help analysts build a conceptual model or a structure of the problem and domain. For example, the system can take the main question the analyst has and suggest a number of possibly related concepts and keywords based on online encyclopedias, table of contents of books, and tagging services. The system should allow the analyst to refine the concepts, so that it can repeat the search and suggest other relevant concepts. By connecting, grouping, and organizing concepts, analysts can continuously build up their conceptual model or structure of the area throughout the process. One analyst cited experience:

Ok, I got to model something, I've got to do a report on Ghana, I don't know anything all about Ghana, where's the tool that if I hit the button, it gives me a picture of what the relationship is, the model how to think about Ghana? It gives me 60-70% of the solution. But it gives me the ability to input and tweak and change those. Because I want to have a role in that, I can't allow the computers to do all my thinking, you know.

Support for this externalization should occur throughout the analysis process because as analysts learn more about the domain, they alter their way of thinking and refine their visual model. Externalizing the thinking process can also assist analysts when they review their analysis after the project terminates. Supporting this activity would be especially useful because it will inform how the analysts could have done better and the areas that need to be examined if they did a similar project, as the instructor said:

The other thing this model helps you do is at the end of the project you can look back and go, “What did we not have time to do? And how does that impact our company, our estimates?” Because whatever reason we didn’t get to it, this was important, we thought this define the space ... We can sit back and go, ok, how confident are we on our estimates, knowing that our analysis is always at some level incomplete? And it’s always incomplete, but how does it impact our confidence in our product? That’s another way to use this representation.

Support source management—enable managing both pushed and pulled information and organizing sources meaningfully

One prominent characteristic of how analysts think about sources is that they have to be always vigilant of new sources. They often search for the same keywords again to see if any new materials have been added regarding the topic (pulled sources). They also receive news articles through RSS feeds every day and check if they have received interesting information (pushed sources).

This process of searching sources takes more time than one may think, and systems should allow analysts to manage both pushed and pulled information associated with concepts they have identified. For example, a system could populate several concepts chosen by the analyst and store all the pulled sources in a database such as Zotero. Based on sources already found, the system also could recommend push resources such as blogs and news articles. For each source collected, the analyst could express if it is a useful source or not. Analysts commented on this functionality:

Sources are what we have to get, but where is the tool where I can integrate them? My RSS feeds dump into me every morning. But then I do searches as well. Where’s the tool that allows me to integrate all data, the information that is useful for me?

If that kind of system exists, I have the ability to go back and find all my sources. Automatically, this (keywords, phrases) gets populated. And every point, I have the ability to say no or yes, no or yes to a source. But the actual extraction or the pulling, and the organization of that are automatic from that.

Then the list of sources can be organized in a meaningful way—for example, by keyword queries, by tags the analyst annotated, or by date the source was added. The system could also provide several ways of representing source results such as summary and tag clouds. Further support for analysis or visualization of collected sources as a group would be extremely beneficial.

All these technical capabilities currently exist in visual analytics systems. Now, it is important that they be integrated together appropriately.

Support analysis with constantly changing information—integrate collection and analysis in a single system and help analysts use structured methods during collection

As described in the previous section, collection and analysis are not separate but highly integrated processes. Analysts do not wait until all the data are gathered; rather, they start analysis even when they have only a few pieces of information. Through the repeated process of collection and analysis, they revise a frame and use the collected data as supporting evidence for the frame.

One of the reasons why wikis were successfully used in our study was because of its flexibility in structure—it is relatively easy to reorient anything in wikis. While requirements and collection kept changing throughout the process, Wikis provided the analyst teams with enormous flexibility and allowed them to easily restructure the content of the pages.

Currently, many systems provide analytical support assuming that processed data are available. If a system does not support a seamless transition between collection and analysis, it is likely to be less successful in assisting the analysis. Analysts collect during analysis, and they analyze during collection. This differs from the statistical analysis, in which a structure or a frame about how to analyze the data is clearly defined and analysis is done with clean dataset. An analyst mentioned:

If they had more reliable, structured data, I’d use statistical analysis. But intelligence data is unstructured and dirty. You don’t know what the best way to analyze it is until the middle of the process, or even the end of the process.

Multiple visual analytics systems provide analytical capabilities. By supporting more flexible data manipulation, so that analysts can easily import and remove data from the analysis pool, these systems will be more usable, with better integration into the analysis process.

If the processes of collection and analysis are integrated in a single system, this helps analysts apply structured analytical methods such as ACH, social network analysis, geospatial mapping, and decision matrix. In our interviews, two teams mentioned that if they had more time, they would have tried other analytical techniques. Analysts always want to push their findings and triage, aggressively reshuffling their

analysis. One of the most effective ways to do this is to employ multiple analytical methods and compare and contrast findings from each. The ability to try various techniques with the data can help analysts find effective ways for addressing questions and strengthening their analysis.

We had this time crunch. We pretty much got rid of the process of re-evaluating our hypothesis, finding what's the most important to make it perfect, and hitting on that, and going back to the stuff that we didn't deem as important. If we had time, we would fill that in.

Help analysts create convincing production—support insight provenance and sanity checks of analytical products

Production is what differentiates intelligence analysis from general sensemaking, which does not necessarily entail external representation. Even when analysts finish their analysis, they need to convert the results into a concise format, so that decision makers can understand their findings. This can be a tedious and time-consuming part of the intelligence process.

When asked about the most difficult part of their project, two teams mentioned production. Interestingly, this difficulty comes from sanity checking and insight provenance, not simply from formatting and writing issues. The sanity check, or qualitative double-check, takes time because data and findings are derived from many sources and analysts have meshed them through the process of collection and analysis. Analysts need to return to original sources and provide a rationale by which their statements are made. They also have to add references to their statements, for which they have to revisit original sources. The following quote from an analyst illustrates those difficulties:

Most difficult part ... basically going back through all the sources we used to grade these technologies, people, and companies, then taking basic pieces from those and making a narrative out of it. So explaining why we thought they are the keys and then relating it to the rest of the other findings.

A system that promotes simple insight provenance during analysis could help analysts save their time in production.

Support asynchronous collaboration rather than synchronous collaboration for exploratory analysis

We discussed three different layers of collaboration in the intelligence process and that the degree to which

technology can contribute varies. In particular, visual analytics systems seem to have the potential to help collaboration in “sharing” and “content.”

From our study, we found that these types of collaboration tend to occur asynchronously, rather than synchronously. When meeting face-to-face, analysts did not work on actual tasks but spent time checking their status, coordinating next steps, and discussing issues. Even when they worked in the same laboratory for several hours, team members took their own computer and worked individually. Although they often talked to each other, it was for simple coordination issues or specific questions about the content. One analyst stated about his perception on collaboration:

We discussed how each of us interprets the data. We're very group-oriented when it comes to discussing to a consensus. Other than that, we prefer to work individually especially for the actual analysis. Of course we collaborate even when we work on our own parts, but there's no one who really knows about those concepts or entities like you do.

In our study, wikis were effectively used for asynchronous, calm collaboration—by making collaboration status visible, encouraging discussion and communication of ideas, and allowing individuals easily to review and edit others' work.

In a nutshell, analysts collaborate cognitively. Rather than trying to build a system that allows analysts to work at the same time in the same workspace, providing a system that not only promotes individual workspaces but also provides asynchronous collaborative features—such as the ability to share sources and data, view and comment on others' work, and merge individual work together—would appear to be more beneficial.

Note that our findings are based on strategic intelligence. In other types of intelligence such as tactical and operational intelligence, which form the basis for immediate action, real-time collaboration is also important because such intelligence must be shared and used quickly.

Unifying the pieces

Because their typical processes of requirements gathering, collection, analysis, and production are so intertwined, and it takes considerable time to coordinate between different software systems, it appeared to us that analysts want an all-in-one system that can streamline the analysis process and save their time. In our study, one of the most important reasons for using wikis in the intelligence analysis was because the all-in-one-place nature of wikis allowed the analysts to

shift their attention easily between the four functions (phases) of the process. By capturing most of the process up to date, the wiki serves as an effective platform for starting collection efforts, analyses, and even finished products. When asked about their “dream” system, a few analysts answered:

If I had to go back to the beginning and start all the way over, I should be able to jump back and forth seamlessly between all of these processes. We need a tool that compensates for that.

It should be one program. We spend more time to make it work together. Nothing’s compatible with others. We want a program that syncs all the documents. Help us do our visualization with the documents. A program that is compatible with Excel spreadsheet. Don’t want to open 20 different programs.

Thus, a hypothetical tool that simplifies the intelligence analysis process would function as follows:

- The analyst enters requirements into the system.
- The system suggests various concepts associated with key terms, phrases, and ideas in the requirements.
- The system not only automatically draws connections between concepts but also allows the analyst to draw connections, group, and organize them.
- The system takes the concepts and starts populating them, collecting information sources using the concepts as keywords (pull sources).
- The system uses sources the analyst identified and suggests new articles relevant to the sources (push sources).
- All these pulled and pushed sources are integrated into a source repository.
- For documents in the database, the analyst can highlight important facts and annotate his or her thoughts. On demand, the system extracts entities requested by the analyst.
- For intuitive analysis, the analyst can write reports in a preferred format, walking through each document.
- For structured analysis, the system helps the analyst try a variety of structured methods. It takes all the information identified by the analyst and integrates it directly into the methods.
- At the end of the process, when the analyst produces final output, the system automatically links each statement to relevant sources and the process by which the statement was derived.

Thus, analysts could flexibly move between conceptual model, collection, analysis, and production. The system accompanies the analyst from requirements to

product in a single platform, speeding up the process, as expressed in one analyst’s comment:

If I had something like that, I’d be blazingly fast. I mean I would be able to do this 10-week project in three weeks.

Interestingly, our suggestions reiterate the findings of other researchers who identified the importance of unifying disparate tools in a different domain. In an observational study of the scientific data analysis process, Springmeyer et al.⁴⁸ concluded that “an effective data analysis environment should provide an integrated set of tools which supports not only visualization, but some of the additional functionality” such as capturing the context of analysis and linking materials from different stages of analysis.

Conclusion

In this article, we described an empirical study to understand intelligence analysts and their processes. We observed three teams of student analysts working on typical intelligence problems. Our contributions include documentation of the processes and methods they followed, clarification of issues regarding the intelligence process, and design implications for visual analytics systems for intelligence analysis.

The study has several limitations. We followed only three teams (14 analysts). Also, the analysts were not working professional analysts but were student analysts in training. The analytical questions studied were from strategic intelligence, one type of analysis. Possible future work includes the study of more cases, particularly with professional analysts working on similar or other types of intelligence problems. Of course, the design implications can serve as motivation for new visual analytics systems, ideally created through participatory design with analysts.

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