VAST Challenge 2014: The Kronos Incident

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ABSTRACT

The 2014 IEEE Visual Analytics Science and Technology (VAST) Challenge presented researchers with a single fictitious scenario: the disappearance of staff members of the GASTech oil and gas company on location on the island of Kronos. A group named the Protectors of Kronos (POK) was the prime suspect in the disappearance. Three mini-challenges and a grand challenge were offered. Mini-challenge 1 included multiple types of text data for participants to provide a timeline of key events and characterize the POK, mini-challenge 2 focused on individuals' movement and financial data for participants to provide patterns of daily life, and mini-challenge 3 featured real-time streaming social media and emergency service data for participants to provide hostage and kidnapper information. The grand challenge asked the participants to integrate results and generate a synopsis of events. The VAST Challenge received 73 submissions from 13 countries.

Keywords: Visual analytics, human information interaction, sense making, evaluation, metrics, contest.

Index Terms: H.5.2 [Information Interfaces & Presentations]: User Interfaces – Evaluation/methodology.

1 INTRODUCTION

The Visual Analytics Science and Technology (VAST) Challenges [1] aim to advance visual analytics through a series of competitions. In the VAST Challenges, researchers and software developers put themselves in the role of analysts to determine if their tools, techniques and approaches can address the specified problems effectively. VAST Challenge problems provide both realistic tasks and synthetic data sets, which live on after the completion of each year's challenge and are used for education, software evaluation, and demonstration of new techniques.

The IEEE VAST Challenge 2014 was structured similarly to those that took place in 2008 through 2011, where an overarching scenario drove the development of all of the independent mini-challenges and supported a grand challenge that required the completion of all mini-challenges to answer. The participants were provided the following scenario storyline and motivating statement for their analyses:

> "In the roughly twenty years that Tethys-based GAStech has been operating a natural gas production site in the island country of Kronos, it has produced remarkable profits and developed strong relationships with the government of Kronos. However, GAStech has not been as successful in demonstrating environmental stewardship. In January, 2014, the leaders of GAStech are celebrating their new-found fortune as a result of the initial public offering of their very successful company. In the midst of this celebration, several employees of GAStech go missing. An organization known as the Protectors of Kronos (POK) is suspected in the disappearance, but things may not be what they seem. As an expert in visual analytics, you are called in to help law enforcement from Kronos and Tethys assess the situation and figure out where the missing employees are."

The mini-challenges and grand challenges required a diverse set of visualization, data handling, and analytic skills. Mini-challenge 1 focused on the analysis of text documents in multiple forms, including historical reports about the suspicious Protectors of Kronos, headers from corporate emails, semi-structured employee records, and news stories about the kidnapping. The analytical challenge involved integrating and making sense of the diverse textual information. Participants were asked to develop visual representations that could be presented to the lead of the police investigation to convey change over time. In addition, participants were asked to provide a timeline of important events taking place around the time of the disappearance. Mini-challenge 2 emphasized geospatial-temporal data analysis, combined with financial information. Here contestants received vehicle location data taken from GPS trackers in company cars and trucks. The GPS data was to be combined with city and street map data to allow pattern of life identification for the detection of possible "insider threats" from the company. Credit card and loyalty card use data was available for integration with the GPS data to augment the analysis. Participants were asked to illustrate anomalies in the patterns of life that may suggest criminal activity. Mini-challenge 3 featured a new challenge format: real-time streaming analysis. Participants tapped into streaming Twitter-like social media data, combined with emergency services data, to discern clues to the identities of both hostages and kidnappers. The grand challenge asked teams that completed all three mini-challenges to combine their resulting hypotheses and evidence and construct a comprehensive description of the kidnapping activities

The VAST Challenge 2014 received 73 entries from 13 countries. Forty-five teams attempted multiple challenges.

2 SCOPE OF VAST CHALLENGE 2014

As mentioned above the VAST Challenge 2014 consisted of three independent mini-challenges and a grand challenge. Teams were invited to participate and submit to one, two, or all three mini-challenges and to the grand challenge. This year the challenge committee was asked if a team could submit a grand challenge entry without submissions to all three mini-challenges. While the committee did not deny this request, the comprehensive description of the kidnapping activities did require analyses drawn from all three mini-challenges. As in previous years, any entry required both a written response to questions asked with ample illustrations, and an explanatory video, which was useful for illustrating human interactions important to the solution.

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IEEE Symposium on Visual Analytics Science and Technology 2014
November 9-14, Paris, France
978-1-4799-6227-3/14/$31.00 ©2014 IEEE

2.1 Challenge Tasks

The three individual mini-challenge tasks and the grand challenge are summarized below. Descriptions of the tasks are posted at http://www.vacommunity.org/VAST+Challenge+2014. All mini-challenge materials are archived in the Visual Analytics Benchmark Repository [2].

2.1.1 Mini-Challenge 1: The Kidnapping and a Historical Analysis of the Protectors of Kronos

Mini-challenge 1 forms much of the foundation of the 2014 challenge as it contains information that captures the history of the Protectors of Kronos (POK), GASTech, and the nation of Kronos, as well as the particulars about the kidnapping that took place. The data provided consisted of a collection of text-based files dealing with the kidnapping of the GASTech employees by members of the social movement group POK. The following datasets were provided to contestants:

- A map of the fictitious Mediterranean island of Kronos
- Descriptions of the countries of Kronos and Tethys
- A chart describing the Kronos-based GASTech organization
- A spreadsheet of GASTech employee records
- Resumes and short biographies of many, but not all, of the GASTech employees
- Historical reports about the POK
- Relevant current and historical news reports from multiple domestic and translated foreign sources
- Email headers from two weeks of internal GASTech company email

Questions asked of participants were (paraphrased):

- What is the current and past structure of the POK?
- What is the timeline of events of January 20-21, 2014 (the kidnapping)?
- What are two possible explanations why the GASTech employees may be missing?

To explore this data, participants needed to perform several kinds of data integration activities and analyses to generate hypotheses about the missing employees. The structure of the POK was primarily described in two historical reports dated five and ten years ago. More recent updates could be found in news articles and in some of the other datasets. This was a basic form of investigation into text data that could be supported by classical text analytic tools.

A set of email headers (containing To, From, Date, and Subject fields) allowed participants to establish some sort of a communication network within the GASTech organization during the period for which data was provided. Within that data were clues to POK members or sympathizers plus hints at socialization patterns among employees (e.g., Isia Vann sending messages to Rachel Pantanal who never replies, becoming interesting when considering potential kidnappers and hostages).

2.1.2 Mini-Challenge 2: Geospatial-Temporal Patterns of Life Analysis

Mini-challenge 2's solution required skills in geospatial-temporal analysis, along with the ability to combine various types of data in sensible ways. Without its employees' knowledge, GASTech placed GPS trackers in its company cars and trucks. While not all employees had use of a company car, many did and could use them during work and non-work hours. The GPS data was extracted from the cars for the two weeks period prior to the kidnapping, but not including the kidnapping day itself. GASTech also issued company debit/credit cards that could be used for personal spending, and many employees had loyalty cards for restaurants and shops around Abila city. In the scenario, law enforcement officials were able to obtain the credit and loyalty card data for those same two weeks to support the analysis. Analyzing the combined data sources could reveal clues about the kidnapping and the GASTech employees who may have participated in this activity. There were multiple data quality issues contestants needed to handle as well. The GPS reading were skewed for some vehicles. One vehicle's GPS had considerable problems with its readings accuracy and another had non-contiguous recording resulting in data gaps. In addition, particular locations exhibited deviations in the times at which they posted their card transactions. In some cases, the transactions were logged only in batches once per day; in another location, transactions were delayed by 12 hours, creating the appearance of individuals shopping in the middle of the night.

Participants were asked to determine the general patterns of life for the GASTech employees and to identify notable deviations from normal patterns. The majority of patterns were very regular throughout both work and weekend days. Pattern deviations might indicate suspicious activities or just non-conforming patterns by individuals. Hypotheses about suspicious activities needed to be supported by evidence and/or reasoning. Credit and loyalty card data contained anomalies requiring first, discovery, then explanation. Some employees were co-located during non-work hours, and participants needed to consider whether these were suspicious or not. One employee located near an executive's house could be part of a security detail or could be conducting surveillance.

Credit card data contained typical charges; for example, GASTech employees preferred to use their debit and loyalty cards at coffee houses. Anomalies such as a credit card charge occurring for an employee while the GPS track indicated a different location for their assigned vehicle required additional consideration.

Map data, including shape files of Abila city streets and a visitor's map of the city sites and shops, provided additional support to understanding patterns of life. For example, even though employees' home addresses were not provided, patterns of life analysis revealed where they spent their evening hours, *typically* indicating their home address. Regular gatherings at what appeared to be residences, but not corresponding to any employee's home address could suggest different hypotheses.

2.1.3 Mini-Challenge 3: Real-Time, Streaming Social Media Analysis

Mini-challenge 3 was a unique feature for the VAST Challenge. In this task, contestants needed to analyze a real-time social media stream with messages similar to Twitter posts mixed with emergency dispatch messages. The data consisted of over 4000 messages over a 4.5 hour period. The stream was divided into three parts. The first ninety-minute segment was provided to participants in comma-separated values format as well as a data stream; the second ninety-minute segment was provided as a data stream only. Each of these two streams could be replayed by the participants as many times as desired. The third data stream, covering the final ninety minutes of the data, was available to the participants one time only, beginning the stream at the time of their choice. The streaming analysis requirements were not strenuous. The challenge only requested that competitors provide a snapshot of their analytical tool displaying stream data and the

text of the last post in that stream. These requirements were intentionally kept reasonably easy as this was a new type of VAST Challenge for the community. In addition, some of the descriptive data from mini-challenge 1 were supplied as background information for the contestants who did not attempt that task.

The social media stream included information concerning three major events taking place in Abila over a specific evening. The events included a rally in support of the POK on the west side of the city; a series of traffic incidents involving a black van that initially occur on the east side then progressed to the west side of the city; and finally a major fire in an apartment complex on the east side of the city. The challenge was to form a hypothesis about these events and to decide whether they were relevant to the kidnapping scenario.

The social media stream included features within the data that are common to forums such as Twitter, although the stream contained a higher proportion of potentially relevant and understandable messages. The stream included commentary by "trolls", commenters who try to be disruptive, low volume commenters, and storytelling posters who followed situations from start to end. The stream also included a large amount of "spam lit", posts of quotations and verse that have ambiguous motivations, but may include relevant tags or words.

Participants were permitted to capture the data for analysis after streaming the data, but the primary emphasis was on performing analysis on the streaming data. The key to this mini-challenge was to have software to be able to ingest, process, and provide visual assistance to users desiring to analyze the stream in real time. The ability to form hypotheses, filter information, and to reason over the streams in order to add to knowledge about the kidnapping scenario was of primary interest to the committee.

2.2 Grand Challenge: Craft the Kidnapping Story

The Grand Challenge allowed the participants to integrate the hypotheses and information they analyzed for all three mini-challenges and generate an overall story to describe the kidnapping of January 20 at the GASTech facility. The participants were asked to answer the *who, what, when, where, why, and how* questions about the scenario, and most notably, to identify both the kidnappers and the hostages. The final question asked where the contestant team would choose to deploy law enforcement forces, given both resource and time constraints.

2.3 Review Process

The VAST Challenge committee recruited reviewers with expertise either in visual analytics or related disciplines and domain experts. Ninety-five reviewers participated, each providing from 1 to 9 reviews. Each submission received 3 to 6 anonymous peer reviews. All reviewers were given the opportunity to recommend entries for award consideration.

Review questions were structured to allow reviewers the freedom to compliment or critique aspects of submissions they felt most important. They were asked to provide an overall rating, comments on the overall rating, a review of how well task questions were answered and how well visual analytics were applied, including whether or not innovative tools were created for the challenge.

The VAST Challenge Committee held three separate one-day meetings to determine awards for each of the mini-challenges and grand challenge. During each meeting, the committee considered the reviewer award recommendations and finalized the list of awards and honorable mentions based on all reviewer scores and comments. The committee also identified noteworthy aspects of submissions not sufficiently significant for an award, but of strong interest. Descriptions of these features were captured by the committee for mention at the VAST Challenge workshop.

Table 1: VAST Challenge Awards

Mini-Challenge 1
Tianjin University / Central South University, *MEAT – Multiview Event Analysis Tool of Diverse Data Sources*: Outstanding Results Presentation Supported by Visualizations
Peking University, *Story Explorer: A Visual Analysis Tool for Heterogeneous Text Data:* Excellent Detailed Analysis
Tianjin University, *Multi-view Display Coordinated Visualization Design for Crime Solving Analysis*: Honorable Mention Effective Use of Coordinated Visualizations
City University London giCentre, *Summarising the structure of an organisation and reconstructing a chain of events:* Honorable Mention Novelty in Visualization (the "Chalkboard")
University of Buenos Aires, *The Kronos Incident (Mini-Challenge 1):* Honorable Mention Effective Timeline Visualization
Mini-Challenge 2
Fraunhofer IAIS / City University London, *Analysis in geographic and semantic spaces*: Outstanding Scalable Analysis
Purdue University, *Dodeca-Rings Map*: *Interactively Finding Patterns and Events in Large Geo-temporal Data:* Sponsor's Award for Novel Visualization
Central South University, *A Collaborative Visual Analytics of Trajectory and Transaction Data for Digital Forensics*: Outstanding Visualization and Analysis
Peking University, *MovementFinder: Multiple filters for spatial temporal visual analytics*: Excellent Comprehensive Visual Analysis System
University of Konstanz, *Visual Analytics for Detecting Behavior Patterns in Geo-Temporal Data*: Honorable Mention for Effective Data Manipulation
Virginia Tech DAC, *Safeguarding Abila: Spatio-Temporal Activity Modeling:* Honorable Mention for Effective Presentation
Middlesex University / MASS Consultants, *Patterns of Life Visual Analytics Suite for analyzing GPS movement patterns*: Honorable Mention for Effective Use of a Custom Tool
Georgia Tech, *Exploring Anomalies in GAStech*: Honorable Mention for Effective Detailed Analysis
Mini-Challenge 3
University of Konstanz, *NStreamAware: Real-Time Visual Analytics for Data Streams*: Outstanding Comprehensive Mini-Challenge 3 Submission
Peking University, *Streaming Data Visual Analysis*: Effective Collaborative Streaming Analysis
Middlesex University, *Visual Analysis of Streaming Data with SAVI and SenseMAP*: Honorable Mention for Effective Support for Analytic Sensemaking
University of Stuttgart, *ScatterScopes: Understanding Events in Real-time through Spatiotemporal Indication and Hierarchical Drilldown*: Honorable Mention for Good Support for Situation Awareness
Tianjin University, *ClueMiner: A real-time multi-dimensional visualization system*: Honorable Mention for Good Support for Streaming and Forensic Analysis
University of Buenos Aires, *Mood Analysis:* Honorable Mention for Detailed Discovery (Where's Rachel?)
Grand Challenge
Virginia Tech DAC, *Safeguarding Abila through Multiple Data Perspectives:* Grand Challenge Award for Effective Analysis and Presentation
University of Konstanz, *Using Visual Analytics to Support Decision Making to Solve the Kronos Incident (VAST Challenge 2014)*: Honorable Mention for Effective Analytic Presentation

3 VAST Challenge 2014 Results

The submissions recognized for awards and honorable mentions in 2014 are listed in Table 1. Additional information about the Challenge entries can be found in the Challenge papers included in the VAST 2014 electronic proceedings.

3.1 Mini-Challenge 1 Awards

A key part of mini-challenge 1 included understanding the content of the news media articles presented, but also underlying drivers for the reporting. The team from Tianjin University partnered with Central South University won an award for "Outstanding Results Presentation Supported by Visualizations." Their visualizations included deep analysis of the media, including media bias, as shown in Figure 1. The challenge also required understanding of all the various data sets provided to the contestants. Peking University was given an award for "Excellence in Analysis and Attention to Detail." Their visualizations included a visual comparison of background information about potential insiders at GASTech. An innovation that was recognized by the committee was City University London's Chalkboard (Figure 2). The chalkboard used a familiar artifact as an interactive workspace, enabling a user to organize and manage their hypotheses and evidence as they worked.

3.2 Mini-Challenge 2 Awards

A common approach to understanding the movement patterns of life for the company cars in mini-challenge 2 was to highlight roadway paths of the cars and indicate the position and time relationships in some way (e.g., annotating the map, animating car movements and displaying times). Fraunhofer Institute partnered with City University London received an award for "Outstanding Scalable Analysis" for their illustration of semantic trajectories of vehicle movements helping achieve a deeper understanding of their patterns of life (Figure 3).

Purdue provided one of the most innovative visualizations in this year's challenge and won the "Sponsor's Award for Novel Visualization." The interactive Dodeca-Rings Map visualization (Figure 4) allowed users to see multiple cars' activities over a day (thus providing insight into activities in specific locations), as well as single car's activities over time (focusing on a vehicle's behavior)

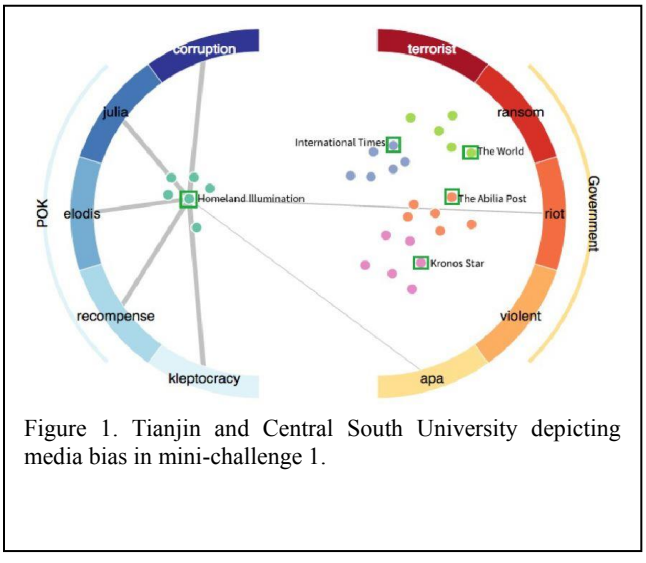

Figure 1. Tianjin and Central South University depicting media bias in mini-challenge 1.

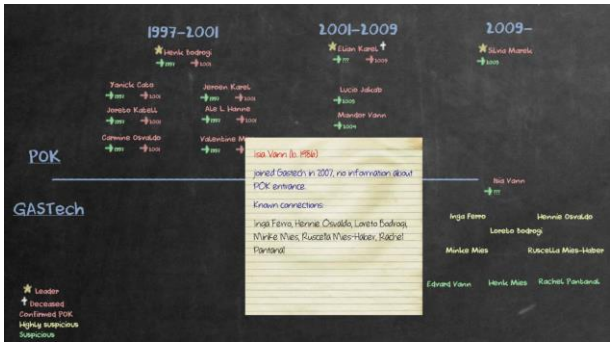

Figure 2. Interactive chalkboard interface by City University London used in mini-challenge 1.

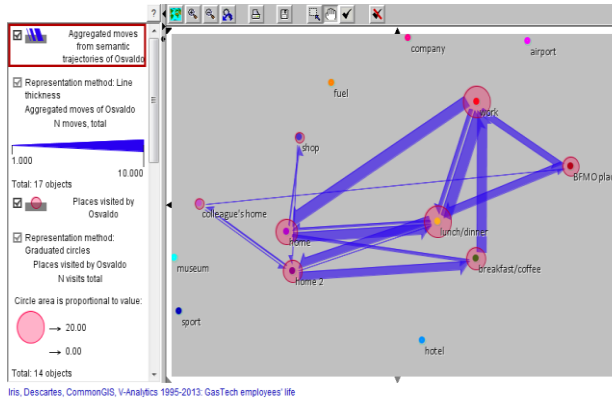

Figure 3. Semantic trajectories of vehicles by Fraunhofer Institute used in mini-challenge 2.

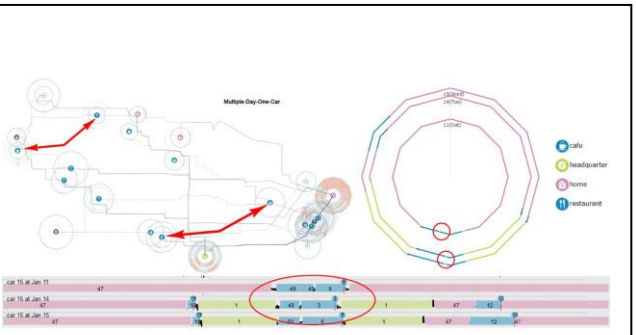

Figure 4. Purdue University's Dodeca-Rings map used to depict vehicle activities in mini-challenge 2.

3.3 Mini-Challenge 3 Awards

Mini-challenge 3 required sophistication in both receiving and processing the social media stream as well as analyzing the stream in real-time. The submission from the University of Konstanz included a detailed description of their processing flow as well as illustrations of the stream analysis (Figure 5). This submission made clear what was discovered during streaming analysis and what was identified through later analysis. The submission from Peking University was also recognized for their effective ability

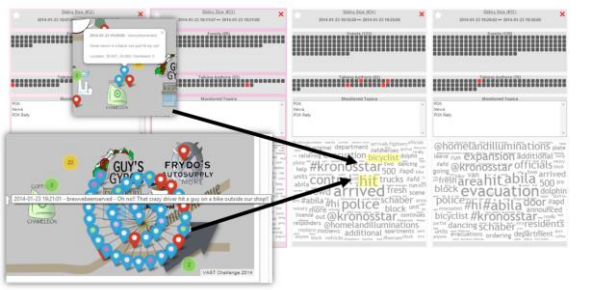

Figure 5. Real-time, streaming media analysis by the University of Konstanz in mini-challenge 3.

dealing with streaming analysis, including creating and editing real-time analysis filters.

3.4 Grand Challenge Awards

Seven teams participated in all three mini-challenges and submitted a solution for the Grand Challenge as well. The team from Virginia Tech was recognized for their thorough analysis and particularly clear presentation of their analytic findings.

Table 2: VAST Challenge Submission Counts

Submissions	2006	2007	2008	2009	2010	2011	2012	2013	2014
Mini-Challenge 1	-	-	22	22	14	30	27	10*	23
Mini-Challenge 2	-	-	13	17	22	8	13	10	30
Mini-Challenge 3	-	-	12	5	17	13	-	11	13
Mini-Challenge 4	-	-	20	-	-	-	-	-	
Grand Challenge	6	7	6	5	5	5	-	-	7
Total	***6***	***7***	***73***	***49***	***58***	***56***	***40***	***31***	***73***

**Mini-Challenge 1 for 2013 received 106 interim submissions.*

4 Discussion

The VAST Challenge 2014 provided a return to a single unifying scenario, with mini-challenges defined to exercise particular analytic and technical capabilities. This section includes observations made by the VAST Challenge committee about this years' competition

4.1 General Observations

The Challenge received 73 submissions across the mini-challenges and grand challenge. This total equals the largest number of submissions to a VAST Challenge in the nine years of its existence, as shown in Table 2.

The mini-challenges were data intensive and teams had to be skilled in data handling, data analysis, and visual analysis to be successful this year. The mini-challenges also featured skill set requirements that had not been required in previous years. In particular, mini-challenge 2 focused on "pattern of life" behavior to enable hypothesis formation and evidence extraction. While mini-challenge 2 contained certain similarities to the health building explosion and evacuation challenge in 2008, that challenge required focus on movement during a single event, as opposed to movements and activities over several days. Mini-challenge 3 was the first to require access and use of streaming data. While first-of-a-kind mini-challenges are often less popular than more traditional mini-challenges, the committee was encouraged by the number of entries received.

Across all of the submissions, the committee noted that participants were rather conservative in offering non-traditional visualization to support their analyses. There were exceptions, particularly City University London giCentre's Chalkboard in mini-challenge 1 and Purdue's Dodeca-Rings Map in mini-challenge 2. The VAST Challenge provides an opportunity for participants to think broadly and creatively, even if the solution may be impractical today. Experimentation in visualization approaches are and will continue to be encouraged even if the results may not be as accurate as those that would have been achieved using a standard approach.

4.2 Mini-Challenge Observations

As is typical with VAST mini-challenges, data included fairly straightforward pieces of evidence to be extracted and used, more subtle clues embedded in the data, and some deceptive data. Straightforward data included mini-challenge 1's historical documents describing the POK over the years, the employee records, country descriptions, and other background material. The news articles and email headers had some subtle features that the committee watched for when reviewing mini-challenge 1 entries. The news articles contained non-English articles that had been poorly translated into English. Data in these articles were often garbled or wrong. These problems did not often interfere with contestants' analysis, although occasionally teams would find data in a poor translation and pursue faulty leads. Some teams ignored these articles altogether, which led to missing bits of information not included in more easily understood articles.

The email headers in mini-challenge 1 represented a network of co-worker interactions at GASTech, including indications of insider threats. They also included clues to one of the kidnapped victims, Rachel Pantanal, whose subplot line we called "Where's Rachel?" Information from the headers, combined with information from mini-challenge 3 social media posts, pointed to her as a victim. Information from the email headers indicated that she was being harassed by Isia Vann, who turned out to be one of the kidnappers. The detail of this plot line was only identified by the University of Buenos Aires "Mood Analysis" team and was recognized by an Honorable Mention.

The problematic data of mini-challenge 2 required special handling to ensure a thorough analysis. Some teams identified the problem data and tossed it out. A more appropriate approach would have been to attempt to incorporate such information where possible, and retain a lower confidence level in a hypothesis due to the data issues. The most successful approaches involved combining the GPS data with the credit and loyalty card data to identify uncertainties and inconsistencies, which in some cases made it possible to identify and correct problematic patterns.

In mini-challenge 3, it was acceptable for participants to perform analysis on the data streams as they were received, but

also to capture the data for further analysis. It was difficult for the reviewers and the VAST Challenge Committee to determine whether participants in mini-challenge 3 actually employed real-time analysis of the social media stream or not. Even with video submissions, it was not always clear whether this had been done. Real-time analysis, even at the slow rate and low volume being delivered in the VAST challenge stream is an important capability to develop for the community. Additionally, the ability to scale the approach to larger, faster moving streams is extremely valuable.

4.3 Grand Challenge Observations

The last time a VAST Challenge incorporated a Grand Challenge was three years ago, as the mini-challenges over the past two years were motivated by different goals. The grand challenge was originally established as a stretch task for highly capable teams, who could handle the breadth of mini-challenges and still have the energy and time left over to perform a cross-cutting analysis that required portions from each mini-challenge to be synthesized into a comprehensive story. The committee has always carefully watched the grand challenge, as it has several characteristics in common with the 2006 and 2007 contests, where participation numbers were rather low. This year, the Grand Challenge was performed by seven teams. However, it was also a highly difficult and time-consuming effort to perform all three mini-challenges and integrate the results. All seven teams participating teams are to be congratulated for attempting this task.

4.4 VAST Challenge as a Research Community Resource

The VAST Challenge Participant Workshop has been held during IEEE WisWeek conferences in different formats for each year since the beginning of the VAST symposium. These workshops highlight outstanding submissions to the challenge and provide a forum for community discussion of needs and opportunities related to the challenge problems, their technologies, and the strengths and weaknesses of the Visual Analytics field. These workshops also have a direct bearing on the scope and scale of future VAST Challenges.

In addition, the VAST Challenge continues to be a source of data and problems used in curricula and student projects in multiple countries. These datasets are also used to evaluate visual analytics tools and provide a resource for researchers and tool providers.

5 Toward VAST Challenge 2015

The VAST Challenge 2015 will be the tenth consecutive Challenge for this competition, a rather significant milestone for both the challenge and for the VAST conference. The VAST Challenge was a vanguard in crowdsourced contests, initiating this format before it had become a popular activity in recent years. The VAST Challenge committee looks forward to this milestone with great enthusiasm.

Acknowledgements

The committee acknowledges the Defence Science and Technology Laboratory (Dstl), the US Department of Defense, Pacific Northwest National Laboratory, and the University of Massachusetts Lowell, for supporting the VAST Challenge.

The committee also acknowledges the support of Diane Steheli and Jordan Crouser of MIT Lincoln Laboratory for consultation and testing of the mini-challenges. The committee also thanks Bertjan Broeksema of Gabriel Lippman for testing of mini-challenge 3.

The committee also wishes to thank Wendy Cowley, Jereme Haack, Scott Dowson, Keith Fligg, Carrie Varley, and Cindy Henderson of Pacific Northwest National Laboratory and Catherine Plaisant at the University of Maryland.

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