

# VAST Contest Dataset Use in Education

Mark A. Whiting<sup>1</sup>, Chris North<sup>2</sup>, Alex Ender<sup>2</sup>, Jean Scholtz<sup>1</sup>, Jereme Haack<sup>1</sup>, Carrie Varley<sup>1</sup>, Jim Thomas<sup>1</sup>

<sup>1</sup>Pacific Northwest National Laboratory, <sup>2</sup>Virginia Tech

## ABSTRACT

The IEEE Visual Analytics Science and Technology (VAST) Symposium has held a contest each year since its inception in 2006. These events are designed to provide visual analytics researchers and developers with analytic challenges similar to those encountered by professional information analysts. The VAST contest has had an extended life outside of the symposium, however, as materials are being used in universities and other educational settings, either to help teachers of visual analytics-related classes or for student projects. We describe how we develop VAST contest datasets that results in products that can be used in different settings and review some specific examples of the adoption of the VAST contest materials in the classroom. The examples are drawn from graduate and undergraduate courses at Virginia Tech and from the Visual Analytics “Summer Camp” run by the National Visualization and Analytics Center in 2008. We finish with a brief discussion on evaluation metrics for education.

## 1 INTRODUCTION

Visual analytics appears in the classroom through the creation of visual analytics curriculum in universities and through special-purpose training classes. Some classes are traditional information visualization classes being reformulated with a visual analytics consideration. Others are new classes specifically created to teach aspects of visual analytics. Visual analytics classes need realistic tasks and data that is similar to that used by professional analysts, so that students can best begin to appreciate the work of professional analysts.

This kind of task information and data is not readily available to schools. Problems and data are often classified or otherwise restricted due to confidentiality concerns. When problems tackled by analysts are available in the literature, the data associated with them are not usually present.

The National Visualization and Analytics Center (NVAC) recognized the difficulties visual analytics researchers would face in the development of applications, requiring data to test and evaluate their systems. The Threat Stream Generator (TSG) project was initiated in 2004 to discover approaches to generating realistic, synthetic test data and to provide challenges and datasets for researchers across the community to use. The TSG team has been making tasks and datasets available primarily through the IEEE Visual Analytics Science and Technology (VAST) contest since its inception in 2006. There are now six complex, heterogeneous challenges and datasets available for researchers to use for evaluation as a result of this contest work. The datasets have been downloaded over 600 times to date.

The challenges and datasets have had a considerable life outside of the VAST contests. They are being used by researchers to help assess visual analytics software in government, commercial, and academic settings. A very exciting application of the challenges and datasets has been in support of visual analytics education. In this paper, we briefly review the design and creation of visual analytics challenges and processes and discuss their use outside of a contest setting. We also describe the use of VAST tasks and datasets in visual analytics coursework at Virginia Tech. A

version of a VAST challenge and dataset was used at the NVAC Visual Analytics Summer Camp, which is also presented. Finally, we discuss evaluation challenges, as supported by VAST datasets in the education setting, and describe additional work needed for educational uses.

## 2 VISUAL ANALYTICS CHALLENGE AND DATASET DESIGN

The general process for creating a visual analytics challenge problem and synthetic data, such as that used for the VAST contest, is described in [9]. When a challenge and a dataset are reused in a different setting than a contest (or for whatever purpose they were originally designed), it is vital to consider the requirements of the new application, and what re-engineering is needed for both task and data.

### Factors in design

Over the course of our research into the creation of visual analytics challenges and data, we rely on the factors depicted in Figure 1 to guide the development process.



Figure 1. Design considerations

Each of these factors must be well-considered for the challenge and dataset to be successful in a particular application. “People” represent the group using the challenge and dataset, for example, university researchers. “Tasks” are the analysis to be performed with the visual analytic tool. “Processes” are the analytic techniques to be used. “Tools” are the visual analytic applications to be assessed. “Goals and results” are the anticipated outputs of the visual analytics tools. “Data” encompasses the type, format, size, heterogeneity, and other characteristics of the challenge dataset. All of these factors need to be considered to create a successful learning exercise. For example, a numeric dataset (as considered under the Data factor) cannot be analyzed by a text-processing software system (Tools). Also, a requirement to use the “Analysis of Competing Hypotheses” method (Processes) will be impossible if it is not supported by the analysis tool. (Tool) or understood by those doing the analysis (People). The difficulty in re-engineering a challenge and dataset varies

depending on the original development goals compared to the new application goals.

The TSG team has worked with teachers and others wishing to use the datasets in educational settings to ensure their proper application and that the necessary changes are made for their use. In general, we try to adjust for the following characteristics:

Factor	Educational Setting Changes
People	Students are just being introduced to visual analytics concepts.
Tools	Software will be constructed from scratch as part of the class.
Tasks	Analyses must be performed during a very short classroom schedule.
Processes	Students will have very limited or no training in analytical methods.
Goals/Results	Class projects must conform to the instructor's goals, emphasizing the class requirements.

For the most part, the task and dataset changes involve ensuring the task complexity is reduced from that of the contest, the task must allow demonstration of the class requirements in the use of software, the data must be reduced in complexity and size, and there should be little expectation of the application of formal analytical methods. With careful considerations, the VAST datasets can then provide a valuable tool for visual analytics education.

### 3 VAST DATASETS IN UNIVERSITY COURSES

We present experiences and lessons learned from their usage in two Computer Science courses at Virginia Tech. The tasks and datasets are applied in these courses from the perspective of constructing interactive software tools that support analysts in analyzing datasets like these. That is, these are courses on tool building, not on the practice of analysis, although a useful side effect is that students did necessarily learn some about analysis processes as a by-product.

#### *Graduate Course on Information Visualization*

CS5764 Information Visualization (InfoVis) is a research-oriented graduate course that focuses on visual representation and interaction techniques (<http://infovis.cs.vt.edu/cs5764/>). The IEEE VAST 2007 Contest, which used the “Blue Iguanodon” dataset [2], was assigned as the class semester project. This dataset contains approximately 1700 documents, such as news stories and blogs, and a pre-processed entity database of approximately 8000 entities extracted from the text documents. Students worked in teams of three to four people to design and build visualization tools that would help them identify the ground-truth story hidden within the dataset. Unfortunately the course occurred after the submission deadline for the contest (fall semester), so students could not submit their solutions. Nevertheless, the dataset proved very valuable to the pedagogical goals of the course.

We initially believed that the project might be too difficult, but were surprised that three of the six teams succeeded in uncovering most of the solution with their tools. Two of these teams focused on network visualizations that enabled them to find important social networks or entity chains within the document collection. The third team created a novel approach for keyword queries with visualization of intersections between results. The remaining three teams got stuck examining surface-level distracters in the

dataset. The visualizations that were least helpful were those that focused primarily on geography or time attributes.

The assignment was challenging for the students. The text-intensive dataset is not a simple multidimensional tabular database that would afford straightforward visual encodings. Also, the pre-processed entity lists were automatically generated and so contained a significant amount of noise. For example, a single person's name might be in the list several times in different formats (e.g. different orders of first/middle/last names, initials, prefix, suffix, etc.). Hence, the data required students to undertake data processing steps that are not necessarily relevant to the specific goals of an Information Visualization course. However, it did give students an appreciation for the broader challenges associated with analysis of realistic data. The students rose to the challenge, but it would be better to slightly simplify the entity dataset.

Because an important measure of the quality of a visualization is its support for finding answers, finding the dataset solution was included as a part of the students' final grade. We used the same answer submission template developed by the VAST Contest organizers, in which the students documented their analytic process and how their tools helped or hindered them in that process. To score their answer hypotheses, we partitioned the solution network provided by the TSG team into weighted components and used that to gauge the percentage of the solution that was found by the students. Points were not subtracted for other incorrect hypotheses. However, the majority of their grade was based on several deliverables throughout the semester that documented their progress in the requirements analysis, design, development, and evaluation phases, as well as the instructor's judgment of the overall technical quality of their final product based on course content.

We observed several benefits of using the Blue Iguanodon in this course:

- It forced the students to address the issue of scalability of data in visualization, and confront the design issues that arise when dealing with large datasets. In past offerings of the course where students could pick their own project topic, students tended to produce visualizations that could only display a small dataset, which is easy from a design perspective and not useful in practice. For example, in a previous semester we used a different dataset that contained only about 50 short intelligence snippets for the semester project, and this resulted in overly simplistic designs.
- It helped the students to realize the value of information visualization. Typically, there are several skeptical students in the course who favor more automated approaches to data analysis. This project revealed that while computational approaches can identify many connections in the data, human-in-the-loop analysis is required to see the data, read the documents, and understand the deeper subtle stories that make up the hidden ground truth (e.g. understanding the motivations of the scenario actors).
- The realistic nature of the dataset, combined with a hidden ground-truth solution, created an exciting and motivating challenge that the students enjoyed. The students felt connected to a larger agenda, and gained an appreciation for visual analytics and the domain of intelligence analysis. Since all of the student teams work on the same project topic, there was also a healthy competition and curiosity between the teams as they wanted to see what solution tools and answers the other teams discovered.

### ***Undergraduate Course on Human-Computer Interaction***

CS3724 Introduction to Human-Computer Interaction (HCI) is a practical undergraduate course focusing on the usability engineering process (<http://www.cs.vt.edu/undergraduate/courses/CS3724>). The project framework was similar to the graduate course. In this class we used the “Stegosaurus” dataset, which consists of approximately 240 documents, mostly news articles and a few maps and supporting documents, and a database of approximately 3000 extracted entities.

We chose this dataset for several reasons. It is significantly smaller in size than the Blue Iguanodon, and the entity data was carefully manually cleaned. The scenario also included a known critical event, which simplified the analytic process by providing a starting point. It could be solved in approximately 2-6 hours with standard tools. This was a good match for the course, which targets 3<sup>rd</sup> year undergraduates, since it placed emphasis more on designing usable interfaces that support the overall analytic process, and less so on data visualization. Thus they could work towards solving the dataset with standard tools, and identify and address critical usability problems or areas for improvement along the way. Also, the dataset solution had not been publicly released, since it was used for the invitation-only live contest at IEEE VAST 2007, so students could not search online for the solution or results. Overall, the difficulty was about right.

A specific difficulty with this class was finding expert analysts for the students to observe during the early requirements analysis phase of the project. A solution that worked reasonably well was to have them observe the instructor’s graduate students analyzing a similar dataset, and to observe each other as they analyzed the Stegosaurus data. We also supplemented this observation phase with other background materials about intelligence analysis, such as *The Psychology of Intelligence Analysis* [4] and *Intelligence Essentials for Everyone* [7]. However, while the background materials helped to set the mood, we found it more valuable for the purposes of the course to keep the students focused on specific issues associated with analyzing datasets like Stegosaurus, rather than the broad and general content of the background materials. In this sense, the dataset provided a specific concrete objective for the students’ projects that was very helpful.

Eight of the 10 teams succeeded in solving the dataset ground-truth, and the other 2 teams found about 50% of the answer. Many of the teams developed tools that acted like a dynamic whiteboard to help them find connections, track their findings as node-link diagrams, and quickly link back to marked-up source documents (e.g. similar to Analyst’s Notebook [5]). Various integrated search features were also found to be very helpful. A major differentiator was whether the node-link diagrams were manual (created by users) or automatic (parsed from the data), and students should be encouraged to consider how these seemingly opposite approaches might be combined.

The evaluation phase of their projects had two components: (1) a benchmark study of external users performing specific short tasks, and (2) a longitudinal study of themselves as they analyzed the Stegosaurus dataset. The 2<sup>nd</sup> part was most enlightening for them as they witnessed first-hand how their tools helped or hindered their own analysis. Searching for the ground truth hidden in the data is what convinced them of the value of usability engineering. It helped them to understand that usability is not limited to learnability (making tools that are easy for novices to learn), but also includes expert performance (making tools that help experts solve hard problems over long periods of time).

At the end of the semester, 17 of the 40 enrolled students responded to our survey as follows. What percentage of the articles in the Stegosaurus dataset did they read to determine their

hypothesis? Answers varied widely from 5% to 100% of the articles, but most said either 20% or 100%. Estimate the time to generate your hypothesis? Answers ranged from 1 to 10 hours, with an average of 4.1 hours. When asked about the most important lessons learned, most answered about the importance and difficulty of good usability engineering and teamwork. We believe the use of the Stegosaurus dataset played an important role in making usability engineering real to these students.

### ***Lessons Learned***

At the beginning of the semester in each course, we used a separate smaller dataset as both an in-class exercise and follow-up homework assignment to introduce the students to the problem domain and spark discussion about potential visual analytics tools. The dataset was designed elsewhere for teaching intelligence analysis methods, and could be solved in a single class period. It contained approximately 50 short fictional intelligence snippets, including arrest reports, intercepted phone calls, bank transactions, etc. This exercise was very helpful and motivating. However, the smaller dataset was too different from the larger datasets. It focused on typical terrorist bomb plots and included more diverse data entities, such as phone numbers and bank accounts. Whereas, the Stegosaurus and Blue Iguanodon scenarios cover a broader spectrum of illicit activity such as drug smuggling, and contain more homogenous text articles. Thus, while motivating, the exercise tended cause some students to overly constrain their potential hypotheses in the larger datasets to bomb plots, and led to tool design ideas that were not helpful. So students should be cautioned, or a more closely matched motivating exercise should be chosen.

More directed background materials for the requirements analysis phase are needed. These materials should focus on how analysts analyze a dataset like this; perhaps a video of a complete scenario that students can examine in detail and derive requirements. Unfortunately this doesn’t give students the opportunity to probe with questions. Since the number of students is much larger than the number of available domain experts, we plan to conduct live in-class observation exercises in the future.

At the end of the semester, a live competition on a 2<sup>nd</sup> dataset (similar to the VAST live contest) would help the students to further convincingly evaluate their designs. We had decided against this because we thought that students would hardcode their tools to the assigned dataset and it would be too difficult to load a 2<sup>nd</sup> dataset for live competition. However, from the survey of the undergraduates, we found that none of the responding student teams hard-coded their projects, and could have loaded another similar dataset with only a small amount of programming or database effort. Thus, we plan to add a live competition to the project in future offerings of these courses.

These datasets worked very well at both educational levels (undergraduate and graduate), and for different types of tool-building course topics (usability and visualization). Important characteristics of the datasets are the following:

- The ground-truth motivated students by the intellectual puzzle, enabled students to gauge their progress, supported evaluation and grading, and clearly demonstrated the value of good methods. For the students, these assignments were more intellectually satisfying than other assignments that ask students to simply look for something interesting in a dataset [6].
- The datasets are realistic and the topic domain is timely and culturally relevant. Students are curious about intelligence analysis in general.

- Getting the right size dataset is critical. If it is too small, students will generate toy solutions without understanding design challenges. If it is too large, students will not have enough time during the semester to complete. These datasets were appropriate.
- Providing a starting point for analysis in the dataset scenario helps students make initial progress on the project sooner, and enables more steady progress throughout (rather than a sudden serendipitous eureka), which better matches educational goals and methods.
- Clean data was important, as some students in the graduate course spent far too much time on data cleaning and processing, and then gave up on designing user interface features that would have been valuable. Blue Iguanodon's entity database should be cleaned and filtered down. Stegosaurus did not have these problems, because the entity database was manually cleaned a priori.
- Solutions must not be publicly available (students will search for them), but available to instructors. This indicates the need for additional datasets for educational purposes that are not used in the open VAST Contests.
- There must be multiple similar datasets for use in in-class exercises, observations, and a final live competition. Because of the nature of the textual data type and task of these dataset scenarios, it is possible to create endless variations for repeated evaluations. The number of possible ground truths is essentially limitless. Answers cannot be found with an automated process or query, and finding the answer in one does not help with finding the answer in another. Yet, because the datasets are equivalent in type, it is easy for students to construct solution tools that can load additional datasets and help solve them, for further evaluation purposes. These characteristics are much harder to achieve when hiding ground-truth patterns in fictitious quantitative datasets.

The datasets were mostly homogeneous, consisting primarily of text news articles. Hence, useful quantitative visual mappings had to be generated from derived data, such as search hits and keyword counts, so there was less use of those types of visual encodings. Entity databases were useful for generating network oriented solutions. The more successful solution tools were those that integrated keyword or entity search features into the visual representation, focused on enabling users to build up their hypothesis, and focused on one primary representation, usually network oriented.

Several student teams were tempted to create comprehensive solutions that offered multiple views for all possible perspectives (network, time, geography, keywords, etc.), but quickly became overwhelmed and produced poor usability. Representations of time and geography were not very useful because they are not critical to the answer, the data was difficult to extract, and the date and location of the articles were not necessarily relevant to the events described in them. Students should be cautioned against overly complex solutions. Another alternative is to attempt a larger collaborative effort by the class as a whole to produce an integrated solution, with individual teams working on portions.

With this project assignment, one might expect a fairly homogenous set of solution tools created by the students. However, there was a surprising amount of diversity, indicating

that there is much room for creativity with these datasets. Also, among the solutions that were similar (e.g. network oriented solutions), students could recognize how even minor design differences had significant impacts.

In evaluation, it appeared that the quality of the students' solution tool did not necessarily correlate with how much of the ground-truth answer they discovered. Finding the answer was a helpful measure, but certainly not the only measure. Given the educational setting, importance was placed on the usage of methods and techniques learned in the course, and meeting milestones during the semester. There are a few reasons for this effect:

- With Blue Iguanodon, there is no clear starting point in the scenario, so students must start by searching for anything 'interesting'. In some cases, students seemed to serendipitously stumble upon the key component of the answer, which then easily led to much of the rest of the answer. Thus, students either got most of the answer or none at all. Whereas, with Stegosaurus, the presence of starting evidence enabled students to make some initial progress quickly and then had to make several additional connections to fill in the entire story, so there was more steady progress and meaningful distribution of percent completion.
- Some students pursued directions in their design (e.g. geographic views) that turned out to be unhelpful for finding the ground-truth in this particular scenario. In some cases, their designs were solid and might be useful in other scenarios, but just not in this particular scenario. Some pursued high risk approaches that did not succeed well. More emphasis on requirements analysis phase could mitigate this, but clearly grading should not be based solely on finding the ground-truth.
- Some students are simply better analysts than others. Using themselves as test subjects is not ideal, although working in groups helps to mitigate the problem. Adding the urgency of a live competition at the end of the semester might also help to equalize abilities. But without ready access to a large number of trained analysts, fair comparative evaluation remains an open problem.

#### *Other Impacts*

Applying these datasets in the courses also served to test and debug the datasets. Some students found formatting errors in the data that could have revealed the solution. Students also pointed out that the use of the fake country name Parazuela, while other names were real (e.g. Argentina), gave away that it was part of the solution. Students also pointed out that, while most of the ground truth was hidden in the many news articles, the additional materials in the datasets such as blogs or images sometimes made too obvious hints.

From an instructor's point of view, the use of these datasets in coursework not only served valuable pedagogical purposes, but also made organizing the course easier for the instructor. The datasets are readily available, easily fit into a semester project framework without the need to develop new materials for a new domain, and contain ground-truth solutions that help in the grading process. We found it to be successful, and plan to continue using the datasets in future course offerings.

## **4 DATASETS AT THE NVAC SUMMER CAMP**

In 2008, NVAC hosted the inaugural Visual Analytics Summer Camp [1]. This camp was a two-week educational immersive session on a broad range of topics in Visual Analytics. Just as dynamic of the field, the group of participants were diverse in that they came from industry and academia, with background experience in analytics, research, development, and entrepreneurship. Attendees came from the National Air and Space Intelligence Center, Mercyhurst College, Simon Fraser University, Middlesex, the College of Charleston and other institutions. The curriculum was designed to provide a sampling of activities performed by professional analysts. These included watch and warn training, analytical writing, evaluation, and analytical tasks to perform using visual analytical tools. Throughout the two-week agenda, the participants were given the opportunity to get hands-on experience with a collection of analytic tools, the ability to network with research leaders in the field, and valuable discussion between analysts and developers.

The tools used during the event included Analyst's Notebook, Starlight, IN-SPIRE, and Jigsaw [3]. In the evaluation session of the workshop, the students were grouped in pairs to work through a VAST challenge with the Stegosaurus dataset using Jigsaw. While one student worked through the problem, another observed their activity with respect to the usability and utility of the tool. The session was held near the end of the workshop, so that students had some familiarity with both the tool and analysis processes. Two of the VAST committee members were there to provide feedback to the students about the analysis, their solutions, and on the evaluation points they discovered. The students provided valuable feedback on the use of Jigsaw from their perspective as novice analysts. Even though the Summer Camp was an intense, compressed educational experience, surveys at the end of the session indicated that the participants found the hands-on experience with the tools and the realistic exercises gave them a greater appreciation for visual analysis.

## 5 DEVELOPING EVALUATION METHODOLOGIES AND METRICS FOR EDUCATION

Conversations with instructors of visual analytics have convinced us that providing them with help in evaluating student projects is a worthwhile endeavor. There are three parts to our VAST contest evaluations: accuracy, interactive visualizations, and process. As described in the preceding paragraphs, students were asked to provide these three components for evaluation. Assessing the accuracy is relatively easy and we provide the solutions to instructors upon request. In the future, this assessment may become even easier as we are implementing an infrastructure as part of an NSF grant [8] that will provide accuracy feedback without providing the answer. Instructors will decide whether they want this feature to be available to their students.

Assessing the visualizations is more of a challenge. There are guidelines for visualizations and for human-computer interactions that can be applied using a heuristic evaluation technique. A separate part of the class projects might be a heuristic evaluation of the teams' projects. Assessing the utility of the visualizations in the context of conducting the analysis is not well understood. For the actual VAST contests, we collect qualitative feedback from both professional analysts and visualization experts. Instructors will probably not be able to obtain these resources for class projects. There are several possibilities that could be used for classroom projects. The graduate projects, described above, submitted descriptions of the process they used in their analysis

including the information they found in each visualization. Another possibility is to have the students first research the state of the art visualizations for the specific combination of data type and analysis to be performed. Students could then identify the limitations of that particular data type and design their visualizations to overcome these limitations.

The most challenging assessment is that of the utility of the visual analysis tool in the context of analysis. The datasets we have been providing for classroom instruction have been somewhat smaller than those for the actual contest but the data types are the same and the scenarios similar. One problem described above is that early classroom exercises do not match well with what is required in the project. One solution would be to give the students the datasets previously used for the classroom project for a longer exercise. They could be required to use standard search tools and office tools to analyze this data. This would give them a baseline to use in identifying problems that their design would, hopefully, overcome. The developed systems could then be used to analyze the larger VAST contest datasets. An option would be to include a "normative process" with the solution to any given contest data. After students had finished their analysis, they could compare their process to the distributed process and submit this as part of a "self-evaluation."

Helping instructors to provide better feedback for student projects should be focused on helping both the instructors and students understand the current analytic processes and current problems faced by the analysts. While providing the datasets and scenarios is a necessary piece of this, we need to also provide an understanding of the processes used by analysts.

## 6 CONCLUSION

The experiences at Virginia Tech and at the Visual Analytics Summer Camp illustrate the usefulness of the VAST contest challenge tasks and datasets in educational settings. Students have benefitted from practical exercises, learned about visual analysis, and were able to apply their new knowledge in the development of analytical software in their projects. From the Virginia Tech experience, we learned that there are various difficulties in having students pick up the task descriptions and datasets alone to attack the tasks. It may help to package the VAST contest with educational materials such as descriptive literature and videos, to support future classroom work. Finally, we have an on-going research need for metrics development for education. Activities like the VAST contest and work through NSF as in the SEMVAST project, will contribute to this in the future.

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