Experiences in Disseminating Educational Visualizations

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Abstract. Most visualizations produced in academia or industry have a specific niche audience that is well versed in either the often complicated visualization methods or the scientific domain of the data. Sometimes it is useful to produce visualizations that can communicate results to a broad audience that will not have the domain specific knowledge often needed to understand the results. In this work, we present our experiences in disseminating the results of two studies to national audience. The resulting visualizations and press releases allowed the studies' researchers to educate a national, if not global, audience.

1 Introduction

For centuries, scientists have been formulating experiments, recording data, and sharing results with others all in the hope of advancing human understanding of the physical world. For much of that time, the sharing of data and results from the experiments consisted of producing equations and sets of charts, tables, and graphs. These methods are typically geared toward experts in a particular scientific field, which makes it very difficult for non-expert individuals to understand the concepts presented and results achieved. This limited ability to communicate important results with a broader community can lead to slowed social progress and misconception of scientific fact.

Visualizations used for public consumption have some extra challenges compared to those visualizations meant for experts with years of training in a specific domain. Scientific experts will often work with those creating the visualizations, which means these domain specialists will have some insight into the resulting images and trust that the results are faithful to the underlying data. Conversely, those in a broad audience might be skeptical of both the scientific computations and the visualization method used to produce images. The general public also requires intuitive visualization methods placed into a self-explanatory context, both which might not be necessary if only communicating the data to experts. Details that might be of great value to domain experts may only serve to confuse those without the underlying scientific knowledge.

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In this article we will describe two visualizations that have been released publicly with the hope of educating a broad class of people. The first is a study of the atmospheric concentration of fossil fuel CO_2 emissions across the continental United States [1,2]. The second displays results of a study of the damage done by the aircraft during the September 11 Attack on the World Trade Center North Tower (WTC-1) [3,4]. We will discuss the public's response to the results, as well as what went right and wrong during the press releases.

2 Studies

2.1 CO_2 Concentrations over the United States

Global warming and its causes have become a very popular topic in recent years. Over the past 20 years it has been confirmed that rising greenhouse gas levels, particularly carbon dioxide (CO_2), have a significant contribution to the climate change problem. Without proper estimates of CO_2 emissions at fine enough scales, atmospheric experts are unable to make meaningful progress on better understanding carbon cycling through the land, ocean, and atmosphere. High resolution fossil fuel CO_2 emissions estimation also contributes to better decision making on emissions mitigation and policy projections.

The lack of high resolution fossil fuel CO_2 emissions data led Purdue University researchers to create the Vulcan Project [1]. The Vulcan Project is a National Aeronautics and Space Administration and U.S. Department of Energy funded project with the purpose of quantifying fossil-fuel CO_2 emissions down to levels as detailed as neighborhoods and roadways. Emissions data was estimated based on a large variety of datasets such as air-quality reporting, energy / fuel statistics, traffic and census data. The data is then combined and sampled to a grid with a resolution of 10 km^2/hr, in all totalling 13 GB. The native data before regularized gridding is even more extensive.

Emissions data gives a good understanding off where fossil-fuel CO_2 emissions originates at the surfaces. But that, of course, is not the entire picture. It is very important to understand how CO_2 is propagated through the atmosphere due to mixing and atmospheric transport. The atmospheric CO_2 concentrations were simulated by inputting the emissions data into the Regional Atmospheric Modeling System (RAMS) [5]. To simulate four contiguous months, the Vulcan-RAMS analysis required about a week of computation on a 50-node Linux cluster.

2.2 World Trade Center North Tower

The attacks on September 11, 2001 began a broad debate about who was responsible, and revealed a broad and deep seeded mistrust of the government. The simulation of the attacked on the North Tower of the World Trade Center (WTC-1) began as a larger scale follow-up to the previously released study on the attack on the Pentagon [6]. The goal of both was to help explain the underlying physics which occurred in both attacks.

The simulation of the attack on WTC-1 first required modeling the aircraft, a 767-200ER, and the structure of the WTC-1 tower. The aircraft was modeled using a cross sectional drawing of the aircraft design and images of components, such as the engines and landing gear. The structure of the WTC-1 tower was modeled from top to bottom, using architectural drawings and first hand expert knowledge. Irfanoglu and Hoffmann [3] further detail the modeling and verification procedures that were used.

The work was only focused on the damage done by the plane colliding with the building. Therefore, in the end, the authors limited the simulation to the top 30% of the building, the region most directly affected by the initial attack. The impact simulations were then run using the nonlinear finite-element analysis software, LS-DYNA, on the IBM 16 processor nano-regatta computer system at Purdue University. The researchers typically simulated the first 0.5 second of the time after impact, which required approximately 50 hours of computation.

3 Visualizations

3.1 CO_2 Concentrations over the United States

Among one of the many goals of the Vulcan Project was to effectively communicate the results of the data to a broad audience. Not only is it important for atmospheric and environmental scientists to understand the data, but it is also important for policy makers and the general public. The visualization researchers worked with domain experts to create a custom program which handles both volumetric and Geographical Information Systems (GIS) data. The use of spatial landmarks was important in the study. It helps convey the information to the viewing public by providing a geographical context.

Like those in other fields, atmospheric scientists were most comfortable with visualizations that were relatable to their own studies. In this case, 2D slices

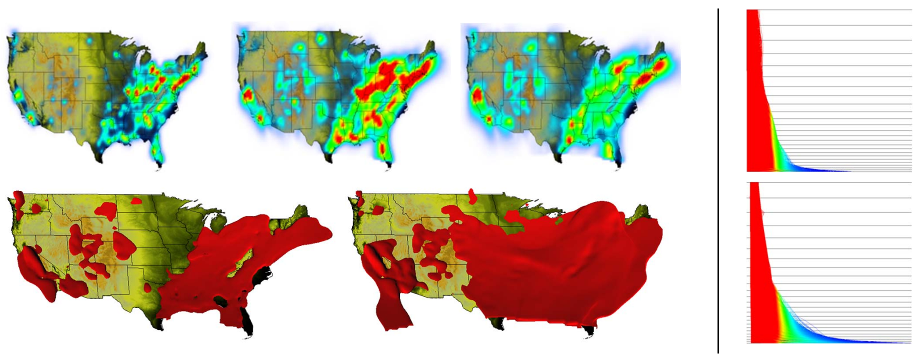

Fig. 1. Some of the visualizations used in the CO_2 press release [2]. The general public was able to best relate with the simpler visualizations (top row and right), but CO_2 experts felt the more complicated volume rendering (bottom) was the most useful.

of data corresponding to various atmospheric heights was a familiar method. The first 2D visualization technique is done by using a color map and blending / shading capabilities to create a composed image of CO_2 concentration values (Figure 1 top). The second technique is Marching Squares and allows for multiple iso-contour values. The later is important for showing areas with higher than critical values of CO_2 concentrations and its evolution up into the atmosphere. 3D visualization was performed using isosurfaces generated from marching cubes (Figure 1 bottom). The use of marching cubes allows CO_2 researchers to easily see phenomena such as CO_2 transport and weather fronts, which had previously been difficult to extract using their prior visualization methods. Visualizing CO_2 concentrations purely at different atmospheric layers, without any regard to latitude/longitude position, brings important insight about the CO_2 transport. To eliminate latitude/longitude, each geographic point is projected to a single line using its CO_2 concentration. Vertical CO_2 columns are connected together with a colored line, with the color indicating the density of points with similar CO_2 concentrations. The drawing of all of these lines together results in a graph that looks similar to a histogram (Figure 1 right).

The visualizations revealed a number of features. 2D visualizations are able to easily show the daily reoccurring atmospheric processes and energy consumption patterns of the United States (*i.e.* rush hour). As a result, the images display greater concentrations during the day and smaller concentrations at night. These images also reveal population centers and locations with heavy industry. 3D visualizations allow the user to easily see the transport of CO_2 concentrations. In the video, the user can see CO_2 concentrations moving from California and into Mexico and from the Eastern seaboard and out across the Atlantic Ocean. One of the more interesting features revealed in the work is the frontal systems in the northern portion of the country. The histogram visualizations also reveal the day-night cycle and properties of the various atmospheric layers. Further analysis of all the visualizations was done by Andrysco *et al.* [2].

3.2 World Trade Center North Tower

In order to create a science driven animation, the researchers filtered and converted the complicated simulation data into something more salient. Domain experts would typically use existing post-processors to read and visualize the output from the simulation. These tools allow for the calculation and visualization of many parameters, such as stress, strain, and pressure. However, these parameters are of limited use when presenting the findings to the general public. For all of the powerful features, which are designed for expert users, the post-processors are completely lacking in the ability to produce a high-quality render for the simulation. After all, this is not the focus of these software packages. The goal of the project was instead to transform the FEA database into realistic looking geometry and place that geometry into the context of the real world. For high-quality rendering of the scene data, Autodesk 3D Studio Max was leveraged. In order to import the data into 3D Studio Max, a custom plug-in was developed which took as input an FEA database and output geometry. This

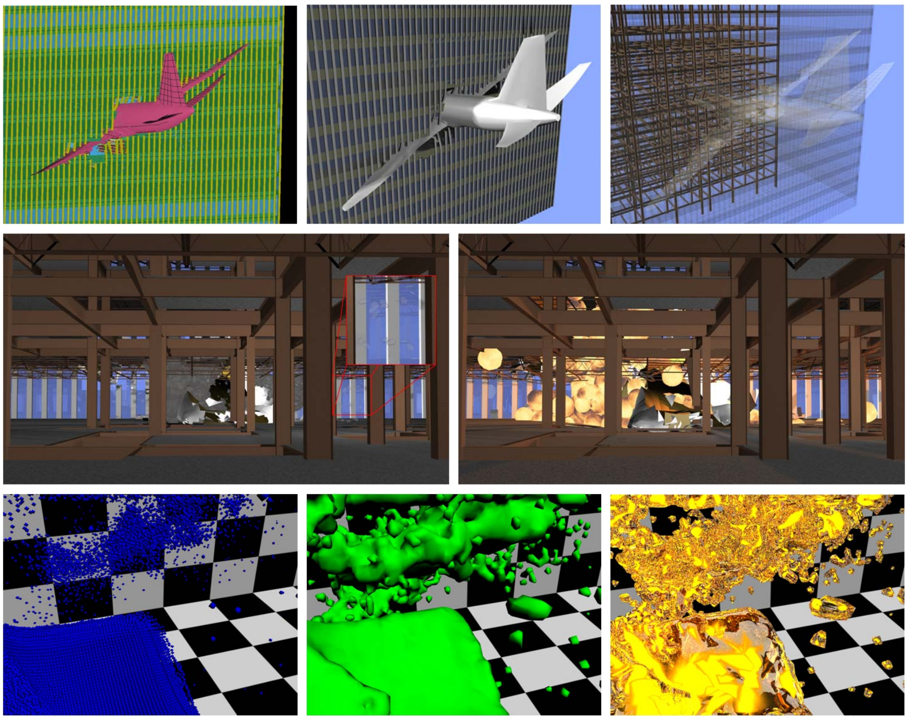

Fig. 2. Visual results of the WTC simulation [4]. Images show outside impact (top), effect of plane on internal structures (middle), and one step of post-processing going from simulation output to creating renderable surfaces (bottom).

geometry could then be rendered with complex materials, lighting, and effects. The 3D Studio Max plug-in generated three distinct types of geometry, shells and beams, fluid, and erosion.

Shells are imported directly as a triangle mesh. Beams, which are stored as 3 nodes elements (two nodes represent the line segment end points of the beam, one the beam orientation) are converted from their three node representation into real geometry which matches the shape of the beam, such as I-beams, square, T-beams, or L-beams. The next type of geometry imported is the fluid, jet fuel. The simulation used smooth particle hydrodynamics (SPH) for fluid calculation. In SPH calculations, the fluid is discretized to a set of points with parameters attached, such as volume, velocity, and acceleration. The fluid was imported as a set of nodes and a BlobMesh modifier (a built in 3D Studio Max tool) was then applied to the node set in order to generate the fluid mesh. The BlobMesh modifier uses implicit surfaces to combine nearby nodes to generate objects resembling fluid (Figure 2 bottom). Although the effects of fire were not considered throughout the simulation, fire visualization was added to improve visual quality. The SPH fluid was used to seed the fire effects (Figure 2 middle).

During simulation, when objects undergo certain amounts of stress they are considered eroded and excluded from future calculation by the simulation software. A special proxy mesh was imported using erosion data which is used to seed special effects such as dust (for eroded concrete) or broken glass shards (Figure 2 middle). To place the simulation into context, the visualization was placed into Google Earth. The impact on the outside of the structure was also used to provide the viewer with a greater sense of context (Figure 2 top). A more detailed analysis of the visualizations was done by Rosen *et al.* [4].

4 Response

4.1 Traditional Media

The video "'Revolutionary' CO_2 maps zoom in on greenhouse gas sources," was released on YouTube March 26, 2008 in anticipation of the official University press release on April 7, 2008. News agencies were alerted of the release of the data and visualizations and many local papers picked up the story along with some major news publications, most notably New York Times, Scientific American, and Wired. The video "Scientists simulate jet colliding with World Trade Center" was released on YouTube June 1, 2007, 12 days before the official University press release on June 12, 2007. Similar to the CO_2 press release, the WTC story was picked up by many local papers and written about across the internet. Its greatest success was being shown on a national news program.

4.2 YouTube

For both studies, the main distribution method for the visualizations was YouTube. YouTube provides invaluable statistical tracking features via its Insights tool, which we used to view the number of hits per date and what parts of the video were considered interesting or boring.

Viewership Graphs. Figure 3 (top) shows a graph of the daily views of the CO_2 visualization. On April 6, 2008, the initial news reports, which generally included a link to the YouTube video, generated about 120,000 views in a single day. The view count received a small spike due to another unrelated video posted under the same YouTube account on July 1, 2008. With the release of Vulcan 1.1 (data mapped into Google Earth), on February 19, 2009, the project again made it into the news. This helped generate an additional 9,000 hits for the video. In total, the video has had over 260,000 views by late May 2011.

The WTC daily views are shown in Figure 3 (middle). The first day of the initial press release, June 13, 2008, the visualization received approximately 13,000 views, a number which gradually fell off the following days. That is until June 21, 2007, when the Associated Press picked up the story and the video received over 550,000 views within a single day. Since that time, the video has continued to receive 4,000-6,000 views per day, with the exception of September 11, 2007

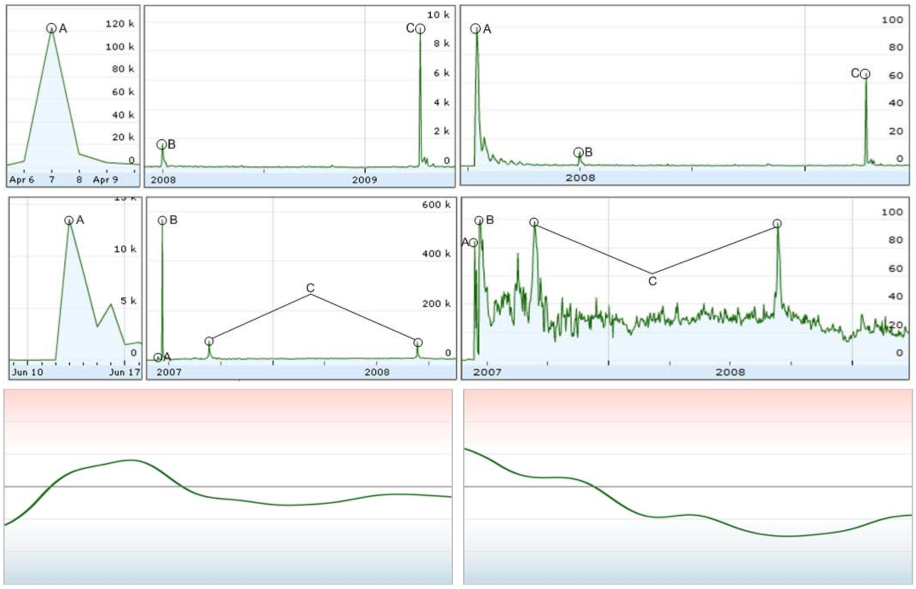

Fig. 3. Top: Daily views (left and middle) and popularity relative to all other YouTube videos (right) for the CO_2 video. (A) Initial press release. (B) Spike caused by release of an unrelated video. (C) Vulcan 1.1 released.
Middle: YouTube graphs for WTC showing daily views (left and middle) and popularity relative to all other YouTube videos (right). (A) Initial press releases. (B) Associated Press picks up press release. (C) Anniversary of the attacked.
Bottom: Hot / cold viewing map for the CO_2 (left) and WTC (right) videos.

and September 11, 2008. On the anniversary of the initial attacks, the video received over 75,000 views each year. The video has received over 10 million total views by late May 2011.

Hot Spot Graph. The YouTube "Hot Spot" graph shows the viewers interest over the duration of the video. This information is particularly useful for this paper's context as it provides concrete data of what parts kept the viewers interest and which parts they ignored. For the CO_2 video (Figure 3 bottom left), the most interesting part was the 2D surface slice animation over a two month period. It seems that most people fast forwarded straight through the introduction and the static images at the start. Though this part of the video had very informative audio, it was too long and not visually appealing enough. The other visualizations shown were in the "cold" zone, most likely because they were too long and either not visually appealing enough or the viewer got what they needed from the 2D surface slice animations. The video was probably too long as it was originally meant to be 2 minutes but ballooned to nearly 5 minutes to include the numerous visualizations and the educational audio that the atmospheric scientists wanted.

The "Hot Spot" graph for the WTC (Figure 3 bottom right) shows the viewers interest experienced a gradual drop over the course of the video. The dips in the various parts of the graph correlate with the transition to different sections in the video. These natural break points present good opportunity for people to move on to other videos. Viewers most likely skimmed through to the interesting visual effects of these sections. There was a small spike of interest toward the end for viewers to see the end results of the study.

From these YouTube statistics, we believe that the visualizations need to be self explanatory when dealing with the general public. The audio, no matter how informative, does not seem to hold their interest. The CO_2 video showed the most interest when using 2D visualization techniques, which is understandable since the general public does not have the knowledge or insight to make sense of the volume rendering. This is inline with the articles written about the press release, where they highlighted the 2D portions and neglected the more visually complicated 3D. It should be noted that the CO_2 experts found the 3D portion to be the most useful for discovering new patterns in the data, whereas the 2D only validated their models. For the WTC video, the viewers seemed to want to just browse the videos and were mostly interested in being told the result, instead of watching the full video and coming to the conclusion themselves.

4.3 Individual's Comments

Due to the sensitive and somewhat controversial nature of the studies, many people felt the need to express their thoughts and feelings. The viewer feedback came in two varieties, e-mails and comments left on websites.

The majority of e-mails received for the CO_2 project were positive. Many of them were from people who wanted to thank the researchers for doing a work that they thought was very important for the environment. Others wanted to inform the researchers that they were going to use the work to help teach their classes. Another common e-mail was a request from people who wanted to learn how to limit their CO_2 contribution. News agencies and researchers wanted more detailed data of the U.S. and images for the rest of the world, which is the goal of the next phase of the project. A request by one news agency to see the CO_2 mapped to population led to new images being generated and another series of articles on the net. A few researchers and businesses wanted to use the data for their own purposes. The comments left on websites were not nearly as positive. Though global warming was never mentioned in the press release or video; many readers attacked the study because they believed that global warming was a hoax. These people believed the study was a waste of money and that researchers around the globe were exploiting people for profit. They posted incorrect facts to back up their beliefs and to tarnish the work presented. Those who took the opposite view (they believe in global warming or that CO_2 pollution is a serious issue) had heated debates with the negative posters. Other people pointed out the limits of the study, namely that the study is United States centric.

The e-mails received regarding the WTC project were likewise both positive and negative. The positive e-mails praised the work for the effort of making the FEA simulation accessible to the public at large through general purpose visualization, and for documenting the tragic events. The e-mails' authors ranged from civil engineers and simulation experts to relatives of the victims, the latter of which thanked the researchers for confirming the findings put out by the U.S. government. The negative e-mails ranged from disputing the scientific merit of the visualization to accusations of intentional misrepresentation of the events and involvement in some kind of government conspiracy. Comments on YouTube and other websites are similar to the e-mails received. The WTC visualization has been requested for inclusion in the narrative of the National September 11 Memorial and Museum at the World Trade Center.

5 Conclusions

To communicate to a broad audience, who may not necessarily have a visualization background, it is important to make the images as intuitive as possible. Using a spatial context and other realistic features (*e.g.* the fire added to the WTC video) will make the visualizations more relatable and help to keep the viewer engaged. Similarly, displaying easily perceived events (*e.g.* CO_2 traveling across the country) helps viewers connect to what they are seeing. We also recommend limiting audio and having short and to the point animations in order to maintain user interest.

We found that creating a press release with the intention of massive viewership of the visualizations has both positive and negative aspects associated with it. Perhaps the most positive contribution of doing this work is that it increases public awareness of a scientific study or issue and helps to stimulate a dialog between individual of opposing viewpoints. These visualizations help non-domain experts understand complex physical scientific events by delivering the information which would otherwise be difficult to understand. But be prepared for negative, and sometimes harsh comments. The general public tends to respond positively, but only if the ideas presented reinforce their existing views toward the subject matter. For example, those who accept the theory of global climate change or the generally agreed upon story of the events of September 11th tend to find the visualizations interesting and informative. Those who disagree attack the quality of the work.

Researchers, and their associated institutions, have a lot to gain and lose as well. Administrators tend to favor any activity which will help their institution gain public attention, particularly when the visualization garners positive public attention. However, the researchers and institutions are putting their reputation on the line. Both the scientific experiment and visualization need to have high fidelity. Even minor factual slip-ups by those in the press who are passing word of the the study, will lead to questioning the credibility of the researchers.

These type of visualizations intended for the public often will require hour upon hour of additional work beyond that needed for the initial scientific study. Scientists tend to only be interested in raising their profile within their community and find the additional work to only be a nuisance, lacking in value, and unimportant to the real science. To that end, using website hits and video views is perhaps not an accurate way to measure what kind of impact the presented images and videos have had on people as the subject nature and pretty pictures may have been what generated the statistics. There is little methodology for studying the impact of visualizations on large populations and a more formal approach is future work.

In the end, we believe that a well done scientific study combined with interesting visuals can have a profound impact on all involved. Though we have received many negative comments, we believe those have come from one extreme viewpoint and constitute a vocal minority. The telling of a factual scientific story has most likely educated countless people, which is what really matters. On a personal note, being involved in a work that garners national attention is an unique and rewarding experience which we recommend to all those willing to put in the extra effort.

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References

1. Gurney, K.R., Mendoza, D.L., Zhou, Y., Fischer, M.L., Miller, C.C., Geethakumar, S., de la Rue du Can, S.: High resolution fossil fuel combustion CO2 emission fluxes for the United States. Environmental Science & Technology 43, 5535–5541 (2009)
2. Andrysco, N., Gurney, K.R., Beneš, B., Corbin, K.: Visual exploration of the vulcan CO2 data. IEEE Comput. Graph. Appl. 29, 6–11 (2009)
3. Irfanoglu, A., Hoffmann, C.M.: Engineering perspective of the collapse of WTC-I. Journal of Performance of Constructed Facilities 22, 62–67 (2008)
4. Rosen, P., Popescu, V., Hoffmann, C., Irfanoglu, A.: A high-quality high-fidelity visualization of the attack on the World Trade Center. IEEE Transactions on Visualization and Computer Graphics 14, 937–947 (2008)
5. Cotton, W.R., SR, R.A.P., Walko, R.L., Liston, G.E., Tremback, C.J., Jiang, H., McAnelly, R.L., Harrington, J.Y., Nicholls, M.E., Carrio, G.G., et al.: RAMS 2001: Current status and future directions. Meteorology and Atmospheric Physics 82, 5–29 (2003)
6. Hoffmann, C., Popescu, V., Kilic, S., Sozen, M.: Modeling, simulation, and visualization: The pentagon on September 11th. Computing in Science and Engg. 6, 52–60 (2004)