Visualization in Research and Education

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Introduction

Visualization as a field can be defined as the process of turning data into interactive images to a user provide insight. Humans are very good at processing patterns. Visualization helps to make these patterns apparent to humans so that we may find meaning within them. Visualization, for a computer scientist, tends to be an application that takes in data, and through user manipulation of certain variables, produces results for the user to comprehend. Visualization can be split into different areas. The two areas that my portfolio will include are Scientific Visualization and Information Visualization, so I will only discuss the two.

Visualizations that fall under the umbrella of Scientific Visualization are applications that assist researchers through their scientific research. The Visualization will aid the researcher through their data analysis phase by allowing the researcher to manipulate their data sets in whatever way they choose. An example by Aurisano *et. al* (Aurisano, J. et al. 2015) is the BactoGeNIE, Bacterial Gene Neighborhood Investigation Environment, a comparative genome visualization made for big displays. This particular visualization was made due to two problems genomics researchers faced. The first was that the volume of data available for researchers to study was increasing. The second problem was that the scalability issues that they faced when trying to compare large sets of genomes on a typical computer monitor. Aurisano *et. al* decided to create the visualization BactoGeNIE which allowed genomics researchers to analyze their large genomics datasets by creating projecting the visual representations of genomes on a large display that could be grouped together and color-coded based on which part of a genome the user wanted to focus on, and how closely it related to other genomes. The explanation may sound simple, but as stated in the paper by Aurisano *et. al*, "[...] in the absence of BactoGeNIE, the E.coli analysis would have required complex data mining and time-consuming analysis software." Through its creation, the visualization was able to save the researcher's time and resources by representing their data in a way that was easily understood by users.

Two of my three projects fall under the area of Scientific Visualization because they are also visualizations created for researchers to help tackle certain problems they face when analyzing their data. The At-Risk Artifact Visualization System will allow users to study, compare, and tag 3D models of artifacts found within different assemblages and stratigraphy from an archaeological site. The DKIST Web-Based Visualization System for Solar Imagery Prototype was developed to allow solar physicists at the Daniel K. Inouye Solar Telescope to study images of the sun through the manipulation of certain parameters such as wavelength, stokes parameter, and time.

Information Visualization has the same goal of providing sufficient insight for a certain topic being analyzed, however, the results do not need to aid in answering a scientific research question, but rather, can be more general. A very simple example that was given in the Data Visualization class taught here at UH Manoa by Jason Leigh this past Spring 2016 was a simple image visualization depicting the different ratios of milk, water, and coffee that certain coffee drinks had. Information Visualization is typically used to understand the contents of a certain topic so that certain questions about the topic can be answered. In my case, one of my projects, Kilo Hoku, can fall under this category. Kilo Hoku, at its current stage, is an immersive virtual reality experience of sailing the Hōkūle‘a out in the open ocean. My team and I are developing Kilo Hoku to be an immersive visualization of the elements one would need to be familiar with to understand the basic concepts of Hawaiian navigation. This would be elements such as the parts of the canoe, the Hawaiian star compass, and starlines.

Significance

All of my work has been revolved around Hawaiʻi in different ways. Born and raised on Kauaʻi there are many ways I have used my knowledge of visualization and design to create tools that help preserve Hawai'i-centric knowledge. Through this portfolio, I will present my best works that involve research and educational topics in Hawaiʻi. The projects are at different stages of development, having started on them as early as the summer of 2016. Through these projects, I would like to show the benefit of interdisciplinary collaboration in developing tools for research and education. As I explained in my introduction, creating visualization applications to help answer certain questions can save users resources and time. Visualization also can be built specifically for certain types of hardware. The latest craze being virtual and augmented reality headsets.

Virtual and augmented reality have been picking up in mainstream popularity since the introduction of the Oculus Rift and the Microsoft HoloLens. Research in both VR and AR topics have existed since the 20th century, however, with the introduction of consumer grade VR and AR equipment, development and research for such hardware has picked up in recent years. What VR and AR have to offer in improving visualizations are their ability to immerse the user in a visualization. Two of my three projects, At-Risk Artifact Visualization System and Kilo Hoku will be implemented in a VR environment.

Overall, my portfolio aims to be an example of the benefits of visualization applications have on research and education. Through my two projects in Scientific Visualization I'll be able to show how visualizations can help researchers through their data analysis problems, and through Kilo Hoku, I will be able to show how an immersive VR visualization can help educate users about a certain topic.

Project Descriptions

At-Risk Artifact Visualization System

This project aims to develop a design of an interactive visualization system for at-risk archaeological artifacts. The analysis of artifacts is integral to archaeology, but due to problems such as the artifacts own fragility, ethical disputes over ownership of artifacts, and natural and anthropogenic factors, many artifacts are considered to be at risk of being damaged, destroyed, or inaccessible to researchers. Currently, there are techniques to preserve these at--risk artifacts, however, degradation is unavoidable at every stage of the archaeological process. However, with the increase of cost-effective 3D scanning technologies, the ability to create 3D data products has become available to archaeologists. Here I aim to describe the process of designing a program that will visualize 3D structural data of at--risk artifacts. I will produce a design that will create an intuitive user experience for archaeologists through lessons learned through archaeological experience and research. Through this approach, I will investigate the benefits of a developer experiencing authentic user activities when undergoing the design process to solve problems for fields that require unique design qualities or constraints.

The visualization system itself will be developed in Unity3d Game Engine. Unity has the ability to load in .obj files that will be acquired through 3D scanning. There will be two methods used to create the .obj files. The first is with a Structure Scanner. The Structure Scanner is a portable 3D scanner that attaches to an Ipad. Through an app, one can use the Ipad-scanner combination to create 3D point data of a desired object. The other method of creating the .obj files is through the photo-3D object method. Using an open source software called Virtual SFM, bundles of photos of an object at different angles can be compiled into a 3D model. The hardware that will be used to display this visualization system is one of University of Hawaiʻi at Mānoa's Laboratory for Advanced Visualizations and Applications (LAVA)'s Cyber-CANOEs. With its large screen and capability for multiple users to interact with visualization system, it will allow collaboration when studying the 3D artifacts. This project is currently under development, so the description is subject to change.

Currently, my main focus is collecting data to use in the software. Over the summer I was able to work with the College of William and Mary summer field school in the Miloliʻi valley on Kauaʻi that was lead by Jennifer Kahn. I was able to work with the archaeologists during their lab time to experiment what the best practices would be to use my scanner, and to learn about the different practices and protocol that go along with Hawaiian Archaeology. To collect more data, I have been volunteering at the Department of Anthropology Archaeology Lab here at UH Manoa to scan more Hawaiian artifacts. A lot of Hawaiian artifacts can be considered at risk due to the remote locations they are found in, their age, and conflict between taking or leaving artifacts from where they lie. As a Native Hawaiian, I am developing this software so that Hawaiian artifacts may be better preserved because studying an artifact or site is inherently destructive. Through 3D scanning, artifacts can be left in peace, but archaeologists will still be able to study its relevance and context through the 3D model.

DKIST Web-Based Visualization System for Solar Imagery Prototype

Remotely visualizing high resolution, image-based, data sets acquired by solar telescopes is challenging due to their multi-dimensionality and immense volume. Once fully operational, the Daniel K. Inouye Solar Telescope (DKIST) is estimated to produce an average of 10

Terabytes of imaging data per day. The DKIST Data Center needs a standard tool to visualize and share their imaging data sets with interested researchers and the public. With a goal of being able to visualize and share 100% of all relevant data collected from the telescope with minimal image degradation from compression, I have created a preliminary design of a visualization tool to handle that volume. This prototype is powered by the IIPImage server compiled with the Kakadu SDK to allow for JPEG2000 support. The visualization tool itself is built upon IIPMooviewer, an HTML5-based javascript high resolution image streaming and zooming client (Bertin, E. et al. 2014) . Additional features were added to IIPMooviewer to optimize it for DKIST such as allowing for the manipulation of the parameters: wavelength, polarization, and time. Although JPEG2000 is not widely implemented, and not commonly supported by open source libraries, it proves to be an efficient file standard to handle large astronomical imagery (Kitaeff, V.V., et al. 2014). By adopting the JPEG2000 standard, our prototype allows for efficient transfer rates between the server and a remote user, while providing an extensible framework for the DKIST visualization tool interface.

While developing this project, the development was split into three parts. The first being the development of a method of converting FITS to JPEG2000. FITS is the standard file format for astronomical imaging, but comes at the cost of being quite large in memory size (B. Thomas, et al. 2015). The solution created to compress FITS to JPEG2000 is to first use the data in the FITS file to output TIFF files. From there, the TIFF files could be compressed to JPEG 2000 through a program provided by the Kakadu SDK. The second part was the organization of data. A pseudo-database was created to try to test out the schema that would be needed to hold relevant data and easily query needed images. This was done with a SQL database. The last part was the actual development of the web application. This was done through javascript and PHP, and hosted on an apache server. Since this project was done through an internship with the Daniel K. Inouye Solar Telescope, the version within this portfolio will be slightly edited due to software licenses that are only authorized to DKIST, and not myself. The project will still function in the same way, but the libraries used within my portfolio version of the application will be open sourced.

This project was started at an in internship I had with the Daniel K. Inouye Solar Telescope. DKIST has faced much controversy over its construction due to its location being practically on the summit of Haleakala. Like Mauna Kea, Haleakala is considered a sacred area to the Hawaiian people, especially those who have familial ties with Pele. Haleakala is considered, to some, a part of Pele as the mountain is said to contain her bones. The debate on whether construction should be halted on the summits of Hawaiian mountains is a heated one, but with DKIST already in the middle of construction, this telescope will be around for quite sometime. In light of the controversy, many people at DKIST want to make sure that they are supportive of the local community. They would like the visualization of their solar imagery to not only be accessible to scientists, but also the general community, especially children. Their hope is that the visualization will also allow children to become curious about the sun, so that it may spark an interest in them that may lead to a career in astronomy, solar physics, or any science in general so that more local children will grow up to be qualified to work in science fields that Hawaiʻi is suited for.

Kilo Hoku: VR Hawaiian Star Map

The night sky offers a map to those who know how to read it. Along with the Hawaiian Renaissance, the practice of traditional navigation was brought back to Hawai’i. Through the efforts of the crew and affiliates of the Polynesian Voyaging Society, the knowledge of noninstrument wayfinding has been recovered. A large part of the technique to traditional navigation is to be familiar with particular stars and constellations, and their movement in the night sky. Kilo Hoku, literally "To observe the wreath of stars," is a VR application to help teach users about the important stars and constellations in the night sky in a Hawaiian context. Kilo Hoku will allow users to control and investigate the night sky with the use of a HTC Vive. Through the unique experience VR allows for the user, the user will be able to learn to become familiar with the sky in a more natural way as they are immersed in a VR star dome.

The project will be created through the Unity3d Game Engine and will be specifically built to be used with the HTC Vive, however, other hardware may be considered; such as the Cyber Canoe to allow for multiple users to experience the program at a time. This project is currently under development and details are subject to change.

The project was inspired by my personal fascination with stargazing. Growing up on Kauaʻi, the stars were visible to me almost every night. I learned how to identify constellations, and actually did presentations in a portable star globe to teach other children about the night sky and their stories. I learned about stories from Hawaiian, Greek, and Chinese mythology. With the interest in Hawaiian navigation, I would like to create a way to teach anyone from anywhere how to identify objects in the night sky. In this way I hope that users both will be able to recognize constellations, and learn Hawaiian words so that they may have a foundation to start to understand Hawaiian navigation.

This project has started development in ICS 691 Virtual Reality course taught by Jason Leigh. Developing the VR application with me is Patrick Karjala, Anna Sikkink, and Dean Lodes.

Literature Review

Aurisano, J., Johnson, A., Leigh, J., Marai, G.E., Reda, K. (2015, August 1). BactoGeNIE: a large-scale comparative genome visualization for big displays. *BMC Bioinformatics Journal.*

Bertin, E. Pillay, R. & Marmo, C. (2014, December 25). Web-based Visualization of Very Large Scientific Astronomy Imagery. *Astronomy and Computing,* 43-53.

Kitaeff, V.V., Cannon, A. Wicencec, A., & Taubman, D. (2014, July 2). Astronomical Imagery: Considerations for a Contemporary Approach with JPEG2000. *Astronomy and Computing,* 229-239.

Thomas, B. Jenness, T., & Economou, F. (2015). Learning from FITS: Limitations in Use in Modern Astronomical Research. *Astronomy and Computing,* 133-145.

Student Role

All of the projects I will showcase in this portfolio will have been created by me personally. The only exception would be Kilo Hoku, in which a group of classmates and I created collaborated on a virtual reality experience of navigating the Hōkūleʻa. Kilo Hoku will contain elements that were developed by my classmates, and I will give credit where it is due. However, all of the other projects have been developed and implemented by myself personally in the service of different organizations through employment, volunteering, and an internship. As I continue to develop these projects to be worthy of being presented in my portfolio, I will have assistance by my mentor, Jason Leigh, but he will be assisting me through advice and mentorship.

Timetable

Fall 2016- Submit Portfolio Proposal, Collect 3D data of artifacts, start basic framework of both Kilo Hoku and VR Artifact projects.

Spring 2017- Complete VR Artifact Project, start updating portfolio with projects. The DKIST project was completed in an internship, so it just needs to be set up to be hosted on my portfolio site. Continue development of Kilo Hoku

Summer 2017- Continue updating portfolio, finish Kilo Hoku, create methodology of collecting user data for research

Fall 2017- Collect data for research of Kilo Hoku, write paper & poster to prepare for Honors Showcase

Spring 2018- Finish any things that are still needed, present at Honors Showcase

Resources and Materials

Currently as a student and employee of the Laboratory of Advanced Visualization and Applications (LAVA), I have 24 hour access to it. In the lab I will have access to VR equipment for the projects that require testing on the HTC Vive. I also have access to the Department of Anthropology Archaeology Lab to collect artifact data. As for the solar image data, those were provided by DKIST.