Final Report
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Organization Name: Scripps Institution of Oceanography Visualization Center

Project Name: Interpretation and Dissemination of Coastal, Seismic and Geological Characteristics of the San Diego Region Using Interactive 3D Visualization Techniques.

Address: Institute of Geophysics and Planetary Physics
Scripps Institution of Oceanography
University of California San Diego
9500 Gilman Drive MC 225
La Jolla CA 92093

Project Contact's Name: Atul Nayak

Project Contact's Phone Number: 858 534 5623

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Part I: Project Narrative

1. Accomplishment of expected results

This report describes project activities for the duration of the grant. During the course of this project we worked on projects to solve problems in seismology, the application of computer graphics to specific projects in ocean sciences and the development of ocean observing systems and the design of a new type of display system. We list our most significant achievements below.

I. Study of two significant seismic events in southern California.

Magnitude 5.2 earthquake on June 12, 2005 near Anza, CA.
We examined two unusual events that followed the magnitude 5.2 earthquake near the town of Anza, California, on June 12, 2005. (1) Although the main shock fault was only several kilometers long, aftershocks stretched for at least 50 km along the San Jacinto Fault zone. (2) There was a magnitude 4.9 earthquake 4 days later and 72 km away, near the town of Yucaipa. We tested the hypotheses that the extended Anza aftershocks were triggered by aseismic slip that followed the main shock and that the close space-time proximity of the Anza and Yucaipa earthquakes was a coincidence. We concluded that the extended Anza aftershock sequence was not out of the norm, and instead it results from the improved seismic recording capabilities in southern California. Despite the far reach of the Anza aftershocks, the ratio of the expected and observed aftershock and background seismicity rates in the region shows that the probability that the Yucaipa mainshock was triggered by the 2005 Anza mainshock is 6%, at 98% confidence. We created time-lapse animations and 3D interactive visualizations to assist in our analysis and in the presentation of the final results.

Investigation of the time lag and magnitude differential between the main shock and first aftershocks of the 31 October 2001 Anza earthquake.
The mainshock earthquake on 31 October 2001 had a magnitude of M_L=5.1. The largest aftershock was of magnitude M_L 2.8 (i.e., significantly smaller than the mainshock). We find that the lack of large aftershocks in the initial part of this aftershock sequences is not a limitation of the detection capabilities and is a true phenomenon. We suggest this relatively large magnitude differential is dictated by a combination of factors that includes complexity of the San Jacinto fault system and the lack of large earthquakes in the region in the past ~20 years. Significant updates were made to the text, diagrams and visualizations for the research paper titled '*Aftershock Detection Thresholds as a Function of Time: Results From the ANZA Seismic Network Following the 31 October 2001 Anza, California, M_L 5.1 Earthquake'*. We also created an on-line supplement that contains visualizations that help us discern specifics about the 2001 aftershock sequence.

II. Design and development of a mobile multiple display system.

We collaborated with researchers at the California Institute of Telecommunications and Information Technology (Calit2) and the Center for Earth Observations and Applications (CEOA) to design and deploy the 'Mobile Interactive Imaging Multi-display Environment' (MiniMe) system. The MiniMe comprises of a cluster of Apple Mac Mini computers and a grid of 15 Dell 24" monitors. Atul Nayak, the principal architect of this system collaborated with Greg Dawe (from Calit2) to design a mounting solution to make the system portable. Nayak and UCSD undergraduate student Dane

Samilo worked on porting various software suites (SAGE and COVISE) to the Mac OS X platform for use on the MiniMe and related cluster computing tasks. Development of scientific tools that use this unique display system are ongoing. The MiniMe system was used at numerous meetings, including Supercomputing 2006, the Fall AGU Meeting 2006 and the American Association for the Advancement of Science Annual Meeting 2007.

III. 3D visualizations of the Huntington Beach experiment.

We collaborated with researchers working on the Southern California Coastal Ocean Observing System (SCOOS) project to create high quality 3D interactive visualizations and high definition renderings of sensors used for in-situ observations in the San Pedro bay. This work was carried out using a visualization software tool called 'Fledermaus' and the Autodesk Maya modeling and animation suite. Using these tools, we incorporated various heterogeneous datasets into a single visualization – for example, we combined USGS aerial photography, high-resolution bathymetry and 3D models of the sensors. We used the OptIPuter Visualization cluster (10 dual processors PC Linux cluster) to distribute the rendering of the high definition movies across multiple CPUs. This has enabled us to define a reusable automated rendering pipeline.

IV. Developing visualizations for the Ocean Observatories Initiative

One aim of this project was to provide visualization content to Scripps scientists (Dr. Jon Berger, Dr. John Orcutt, Dr. Frank Vernon) involved in the proposed NSF Ocean Observatories Initiative (OOI) Cyberinfrastructure (CI) and OOI Global Scale Observatory (GSO). We developed Google Earth and Fledermaus interactive visualizations that let a user navigate to the various sites in the OOI project at coastal, regional and global levels. We rendered high quality animations (using Autodesk Maya) of a new type of mooring called the 'Expandable Draft Platform', which will be one of the central elements of the proposed GSO.

V. Visualization of projected effects of sea-level rises on San Diego coastal areas.

We developed a 3D visualization of a flight over the San Diego coastal regions, highlighting those most likely to be affected by sea level changes over the next century. This animation was produced by integrating draped satellite imagery, recently acquired LIDAR data, and projected changes in sea level according to various ocean-observing authorities. Dr. Tony Haymet, Director of Scripps Institution of Oceanography, presented these results at a meeting of the California Ocean Protection Council in San Francisco.

Note: In our six month Progress Report we described two additional projects ('High-resolution Sub-bottom and Bathymetric Surveys in San Diego Bay' & 'High-resolution survey offshore La Jolla'), which we do not list in this document so that we can keep our narrative to 3 pages.

2. **Unexpected results so far.**

None.

3. Publications and dissemination of results.

The project website is **http://www.siovizcenter.ucsd.edu/sandiego**

- Kilb, D., V. G. Martinov, and F. L. Vernon. "Aftershock Detection Thresholds as a Function of Time: Results from the ANZA Seismic Network following the 31 October 2001 ML 5.1 Anza California Earthquake." Bulletin of the Seismological Society of America, v. 97; no. 3; p. 780-792; DOI: 10.1785/0120060116 (2007).
- Felzer, K. and D. Kilb, "The Southern California Anza Magnitude 5.2 Earthquake of June 2005: An Examination of the Extended Aftershock Zone and Intermediate Range Triggering of the Magnitude 4.9 Yucaipa Earthquake, (in review, 2007).
- Orcutt, J., J. Berger, and J. Halkyard. "The NSF Ocean Observatories Initiative Global Scale Observatory: Expandable Draft Platform." *Eos Trans. AGU, 88(23), Jt. Assem. Suppl., Abstract OS21A-08 (2006)*.
- Brothers, D., G. Seitz, P. Williams, N. Driscoll, G. Kent. "Fault History and Architecture of the Southernmost San Andreas Fault and Brawley Seismic Zone: New Constraints from CHIRP Data Acquired in the Salton Sea." *Eos Trans. AGU 87*, *Fall Meet. Suppl., (*2006).
- Im T., Nayak A., Keen C., Samilo D., Matthews J., High resolution renderings and interactive visualization of the 2006 Huntington Beach experiment, *Eos Trans. AGU 87(52), Fall Meet. Suppl., Abstract IN31A-1318 (2006)*.
- Nayak A., Dawe G., Samilo D., Keen C., Matthews J., Patel A., Im T., Orcutt J., Defanti T., Design of a High Resolution Scalable Cluster Based Tile Display or Earth Sciences Visualization, *Eos Trans. AGU 87(52), Fall Meet. Suppl., Abstract IN31A-1309 (2006)*.

4. Development of project participants.

This project is the first opportunity for the PI Atul Nayak to lead and manage a project and conduct innovative research in the fields of display technology and scientific visualization. The project enabled co-PI Dr. Debi Kilb to investigate seismic events and test hypothesis, especially regarding the ability of the ANZA sensor network to record earthquakes of low magnitudes. This project has also provided funds for undergraduate student Dane Samilo's internship salary and has trained him in cross-disciplinary research.

5. Additional funding obtained.

CEOA provided funds for the hardware and software required to construct the MiniMe system. We also leveraged technology developed by NSF-funded projects e.g. the OptIPuter.

6. What did funding from The San Diego Foundation allow you to achieve that would not have been possible without such support?

This funding allowed us to conduct research in the areas of computer science and earth sciences. We were able to test hypothesis in seismology and develop new visualizations and a display system that may define the next generation of tools that scientists will use to conduct their research. We are pleased to announce that, as a direct result of a portion of this work, UCSD won the competition for the OOI CI. Some visualization products were used to secure new funding for Scripps and to present Scripps research to scientific audiences as well as members of our society, especially in San Diego.

Part II: Project Budget

1. Expenditure report

All funds have been utilized over the course of the project (projected balance at the end of June 30 2007 is expected to be $2.29). These include salaries for Atul Nayak, Debi Kilb, Dane Samilo and Laura Cravens-Wertz (Project Administrative Assistant) and costs for telecommunications and supplies. In June 2007, some project funds were also used to pay salaries for Thomas Im (Programmer Analyst) and Alexander Quan (UCSD undergraduate student worker) for project related tasks assigned to them.

Funds were also used for travel to the American Geophysical Union Fall Meeting (PI & undergraduate student worker), for publishing a paper in the *Bulletin of the Seismological Society of America* and abstracts at the *American Geophysical Union* Meeting and for office supplies and books.

2. How will the activities of this project be sustained in the future?

The project has concluded. Some of the activities that include future development of visualizations for Earth and ocean observatories will be continued using funds from the OOI Cyberinfrastructure project and the NSF EarthScope project.