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Project Manager: Rich Schramm

ROV Data Visualization

Requested Budget: $15,000.00
Duration of Project: 3 years (1999-2001)
Date Submitted: 1 June 1998
Project Team: Mike McCann, James Barry, Bruce Robison, Jenny Paduan, Craig Dawe, Rich Schramm, Gerry Hatcher, Don Brutzman (NPS)
Summary of Resources Requested (Total No. of Days per Division for 1999):
- *R&D Total: 110 (99 IAG + 11 Science)*
- *TSD Total:*
- *DMO Total: 3*
- *ITD Total: 15*

ROV Data Visualization

Web-based 3-D visualization and simulation

> *There were three areas of developing technology that I thought would make research in the deep waters of the oceans much more effective in the future. … The third is the progress that is being made in computer science and data communication. Deep water research involves immense amounts of data. I have the impression that much more time is being spent in collecting data than in looking at it and analyzing it. We believe that situation can be greatly improved.*[1]

- David Packard, August 28, 1988

The Problem Addressed

Statement of the problem: Data collected by MBARI's ROVs are deposited into files and databases where they sit in their separate and unique formats. The information in these data sets often go un-visualized, un-interpreted and hence do not effectively contribute to our scientific understanding or help us with our operations. Conducting operations at benthic sites is hampered by an inability to view features on a scale larger than the limit of what can be seen through the ROV's video cameras. For Jim Barry's work at cold seep sites there is a need to visualize an area bigger than a room; the visualization needs to contain objects representing experiments in progress as well as geographic and geologic features. For Bruce Robison's work in the mid-water there is a requirement to better understand the 3-dimensional aspects of his dive data.

Creating interesting visualizations of the variety of data collected by MBARI presents a challenge whose solution may benefit the greater oceanographic community. The assembly of our various data sets into a common, compelling, efficient, and easy-to-use visualization system is the goal of this project.

Why it is important: In several ways oceanography is still a science of discovery and observation. The hypothesis and experimentation steps of the scientific method are supplanted by making never-before-done measurements of natural phenomena. The next step in the scientific method is the construction of a theory or model to help explain what we observe. MBARI excels in measuring and observing oceanographic phenomena; however, our scientists could spend more time looking at and analyzing their data with better

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[1] *Oceanography*, November 1988, p 47.

systems. Our oceanographic data storehouses grow ever larger while our ability to understand and "mine" what is in these data sets is limited by lack of easy-to-use tools. This project aims to create a system for visualizing data using state-of-the-art methods such that scientists can better hone and communicate their theories.

Present state of art/understanding: The World Wide Web has revolutionized the distribution and sharing of data between researchers and with the general public. An example is the July 1997 Mars Pathfinder mission in which NASA shared the results as soon as they were available[2]. The Web is relatively mature in its ability to deliver data and 2-dimensional images to millions of people around the world. With Virtual Reality Modeling Language (VRML), an ISO standard (ISO/IEC 14772) adopted in 1997, complex 3-dimensional shapes and multimedia data can now be efficiently transmitted across wide area networks. Modern web browsers on consumer-grade computers can render this information in a virtual world where users can navigate and interact with multimedia objects with hyperlinks to more detailed information. The ISO standard and necessary infrastructures (the Web and browsers with VRML players) are coming into place. For participants in the VRML community the present task is to apply the technology to real content, such as that possessed by MBARI.

How it relates/contributes to MBARI's mission and strategic plan: MBARI's data sets represent a microcosm of typical oceanographic data. We have Mooring data, CTD and bottle profile data, cruise underway data, and all the data that are collected during ROV missions: CTDO, video, samples, navigation, and video annotations. MBARI's mission is to develop state-of-the-art systems for conducting scientific research in the deep waters of the ocean; this project aims to develop a system for visualizing all of the disparate data that we collect. This technology can also be used to transfer our results to a worldwide audience, much like NASA disseminated the results from last summer's landing on Mars.

Approach to the Problem

Engineering/technology development: This is primarily a software development project. We envision a 3-year plan as detailed below.

Year 1 (1999) - *Getting our feet wet*:

The major software development effort for 1999 will be the development of VRML components that can be mixed and matched to create scientifically useful virtual worlds. These components will initially be combined into two

[2] http://mars.jpl.nasa.gov/index1.html

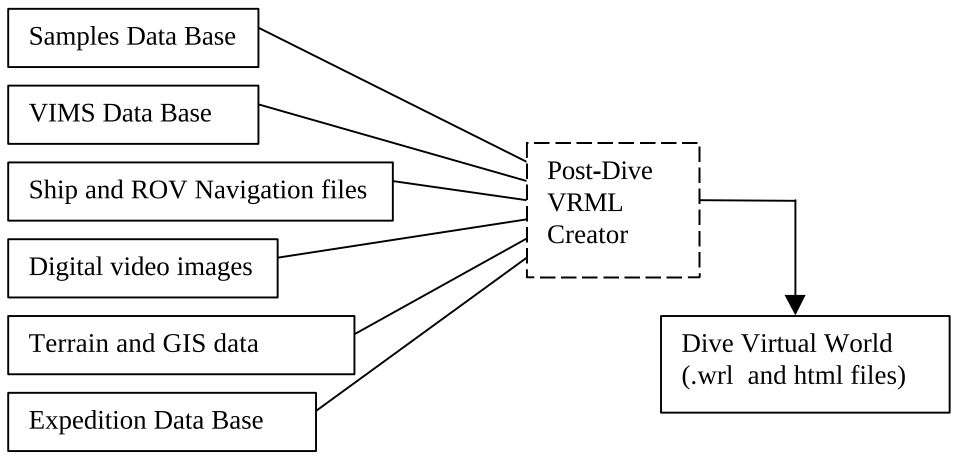
types of products: one type is a stand-alone world where new visualization features can be evaluated and tested for merit, the second is a script to create virtual recreations of each ROV dive. This would work very much like the ROV video frame grab web pages work now, where any web user at MBARI can surf to the expeditions pages on our Intranet and click to get digital images of the previous day's dive. Within the virtual world of the dive, a user would be able to see all the images, all the video annotations, the ROVCTDO data, the paths of the ship and ROV, all within the context of the undersea terrain.

The stand-alone world can be thought of as a laboratory where high-level VRML authoring tools (such as CosmoWorlds) can be used to add objects, create interactive functionality, and understand VRML constructs. Output from these authoring tools is ASCII text. Sections of these text files can be cut and pasted into a script that combines the VRML code and our data. This script can be configured to run automatically each evening for that day's dive so that on the next day anyone can review the dive and all the data that were collected.

VRML technology is a programming and development environment that offers novel scientific visualization techniques. Imagine going to a web page where you see a view of Monterey Bay from high altitude, you press the page down button and fly down to the surface of the ocean where you see a model of the Western Flyer. Click on a button and the water fades away revealing a shaded relief map of the bay. Click on another button and watch the ROV Tiburon descend on a path toward the ocean floor, select the "over-the-shoulder" viewpoint and join Tiburon on its path to the research site. As the Tiburon model travels, line segments are trailed with color coding indicating water temperature, salinity, and dissolved oxygen concentrations. Along the way you see video frame grabs that were taken on the real dive and icons indicating what video annotations were made. At any time you can "fly" on your own and investigate in more detail the image and annotation data. You join Tiburon again and soon here the sound of an acoustic beacon. You are near enough to this benthic site that high-resolution mapping data have been loaded in along with virtual representations of all instruments placed at the site. Representative frame grabbed images are also shown properly oriented according to the position, heading and pitch of the vehicle and camera when the picture was taken. Go in a little closer and see an icon indicating that mud core samples exist for this area. Click on it and data about these samples are retrieved from the Samples database and displayed inside your browser. Curious about the fault structure of the area you pan back and click on button to overlay a geologic map image over the terrain and see it in relation to all of the other data.

Though the above may seem like a fanciful scenario, this kind of experience is possible and we think achievable by the end of 1999. Having a goal to visualize our data this way will help drive much of the data management and coordination that must take place while acquiring data. Tools and processes developed in this project will be a capstone that rests upon other systems and processes in place at MBARI. If a problem develops with any of the data streams (e.g. ROV navigation is poor) then it will be immediately visible within the context of the other data streams that are presented in the visualization.

Data collected from the dive will be combined with the VRML constructs to create the virtual world. The diagram below shows the Post-Dive VRML Creator that will be developed in mostly the perl scripting language.



Creating interfaces to the Samples, Expedition, and VIMS databases will require some modest SQL and Java programming. Perl functions already exist for parsing the navigation, image, and terrain files. Most code reuse will be old-style cut-and-paste; where practical, object oriented techniques in the form of perl modules and Java will be used – a balance will be maintained between formal software engineering and a desire to produce results in a timely fashion through rapid prototyping.

A feasibility study done by 1997 MBARI Intern Jenny Washburn confirmed that video image, navigation, and terrain data can be combined and effectively visualized using VRML technology. Copies of the survey results are available on request. The virtual worlds used in the testing are available on MBARI's Intranet on the *R/V Point Lobos* Expeditions page on the "VRML Views" link.

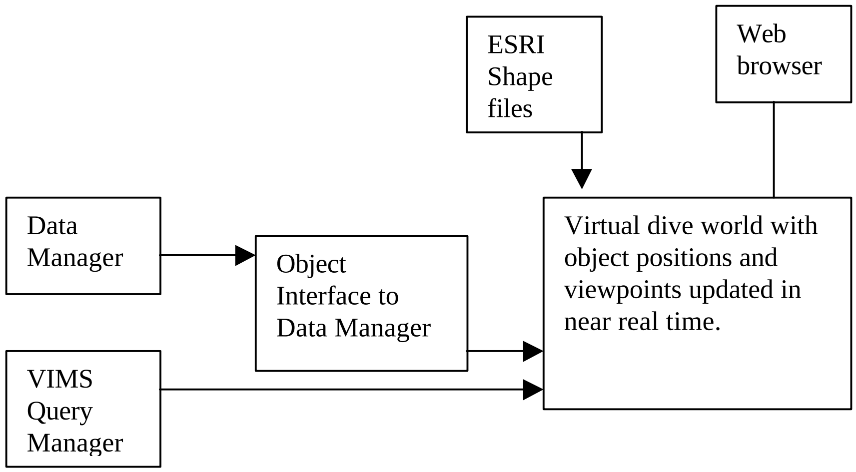
Though this proposal is focused on web-based 3-dimensional visualization, there are many areas where web-based 2-dimensional zoom and pan map-based visualizations would be useful. Web delivery of our mapping data and 2-D geographic display of data retrieved from web-based database queries (such as from the Samples database) is another effective visualization tool. To address this need we propose purchasing a commercial product (Internet Map Server from ESRI) and helping to begin interfacing it between our GIS system, web servers, and other databases. Development of this kind of tool spans multiple projects (Web, Samples, ROV data visualization, Mapping), yet not one of them is explicitly focused on delivering it. This project takes web delivery of 2-D geographic display of data under its wing, allowing other project teams to focus on the data.

Risks: Much of the compelling attributes of VRML virtual worlds are features such as animated viewpoints, higher levels of detail when in close proximity to dive sites, and interactivity, i.e. the user clicks an object in the world and something interesting happens, such as retrieval of information from a database. VRML authoring tools can help with creating the "stubs" of such VRML code, but efficient level of detail and database capabilities do not currently exist within the language. The Geovrml and Database working groups of the VRML Consortium (http://www.vrml.org) are developing conventions that will address these latter two capabilities that we see as essential for truly compelling worlds. If these capabilities are not developed within the timeframe of this effort then widespread delivery of our virtual worlds will be less certain. Computers with hardware accelerated graphics (such as SGIs and newer NT systems with special graphics cards) will be able to render high-resolution texture mapped terrain. Lack of database support within the VRML language will require queries to be executed in advance of the creation of the .wrl file and will limit the data interactivity that we would like to have.

Year 2 (2000) - *Making it operational*:

The visualization tools developed in year 1 may prove worthwhile in expected and unexpected ways. One way we expect them to be valuable is in the actual planning for and operation of ROV dives. Having a real-time simulated world of the environment based on our high-resolution mapping data will help bridge the gap between the distances seen through the video cameras and the resolution provided by navigational charts. Other benefits of having the real-time simulated world in the ROV control room is that past observations or instrument placements (including those from experiments other than the current mission) can be incorporated so that there is a clear understanding of where the vehicle is. Both vessels currently have a mid-level SGI machines available in the control rooms. As part of an upgrade planned by IS for 1999 these systems (ariel and beroe) will be upgraded to SGI Octanes so that they will have enough bandwidth to capture digital stills from High-Definition video cameras. This same computer can also be used for the highest quality and fastest rendering of the VRML worlds right inside the control rooms.

Below is a high-level block diagram of the proposed real-time VRML system.



The effort to create the real-time VRML system is a complement to the existing real-time GIS system. Table 1 at the end of this proposal compares the features of GIS tools, Fledermaus, and VRML. What VRML technology uniquely offers is its inherent 3-D structure and its ability to deliver content over the web.

Year 3 (2001) - *Doing science:*

In the third year of this project we will have the processes to create archive and real-time visualizations under revision control with decreasing time spent on fixing bugs. In 2001 the development activity will turn more toward using the tools for analysis and simulation of scientific questions and theories. Transferring the technology via our web site and through technical and scientific conferences will be a large activity as the project winds down.

Field programs: There are no specific field programs proposed, instead we plan to coordinate with ROV users and pilots to add the real-time visualization capability in year 2 in a non-interfering dive of opportunity type of cooperation.

Data reduction and analysis: This project provides computing infrastructure for automatic and real-time data reduction and visualization so that the scientist is empowered to do analysis and interpretation.

Proposed duration of project and approximate plan of action: The duration is 3 years for several reasons: 1)VRML technology is young and still evolving, by setting a longer timeline we can ride the technology wave and take advantage of new tools and techniques, 2) the technical lead (Mike McCann) will be committed to other projects and cannot spend all allocable time on this project, and 3) results from this proposal are not required for other projects, except for perhaps the telepresence/teleoperation proposal. In contrast, results from other projects are in the critical path for this visualization proposal. For example, in year 2 we need to interface with the distributed object interface to datamanager and the VIMS queryManager. These are proposed in the Telepresence and VIMS enhancement projects. If these projects are not approved, this project is not affected until its second year, and should this happen we can address that in next year's proposal.

Specific Deliverables

Products from research:

Tools: Automatic generation of visual simulations of the previous day's dives made available on MBARI's internal web site. Data presented include ROV-CTDO, VIMS/Vicki annotations, samples collected, and traps deployed within the context of our high-resolution mapping data available from MBARI's GIS system (Year 1). A real-time 3-D view of ROV location within the context of a simulated environment will be available for use aboard our research vessels (Year 2). Extensive simulations of one or more benthic and mid-water sites to include temporal and spatial variability of biological communities and other processes such as cold seep plume dynamics and inter-annual physical oceanographic processes (Year 3).

Publications: A paper to be submitted to a refereed computer journal is planned for 1999. The application of VRML technology to visualize data and operations within the deep sea is currently unique within the VRML community. We envision that scientists can use the results of this project to present results of their work at their conferences. A presentation at the Fall 1999 AGU meeting is planned in conjunction with papers that MBARI scientists will present there. More publications and presentations will follow as progress is made in years 2 and 3.

How success will be measured:

The VRML worlds we create will be delivered to users from Web servers. The log files from these servers can be analyzed to see how many people access and view the worlds. This will give us a metric to track use over time. However, our real measure will be if our own MBARI scientists actually use the tools we develop to advance their research. If no one is using the tools in the second year of this project then it is failing and it should de-scoped or canceled.

Project Team

Who will be working on this project?

Rich Schamm will provide overall project management support to include budget authorization, milestone and task tracking as well as coordinating the efforts of IAG members working on the project.

Mike McCann will act as the technical lead. He will write the scripts that create the VRML worlds and integrate them with existing systems and processes. He will also be the primary interface to VRML development activity that may take place at the Naval Postgraduate School. If this proposal is approved then he would spend about one half of his allocable time on this project.

Bruce Robison and James Barry are the scientific leads and the primary customers of our work. Their role is to give direction on what features in the virtual worlds are most important and to evaluate our progress at specific checkpoints; for this we are requesting 3 days each of their time in 1999.

Jennifer Paduan is our ITD member and coordinator of the Samples database. She will help with integration of samples in the virtual worlds and act as an end user and as our scientist for beta-testing services.

Craig Dawe's role will be in year 2000 when we plan to install the real-time VRML worlds on board our vessels. However, his participation in a project review sense will be required in 1999 as we develop the VRML constructs that we expect to use for the real-time tool.

Prof. Don Brutzman at the Naval Postgraduate School (NPS) will participate as a volunteer external collaborator. As a thesis advisor for computer science and systems management students, Don can help direct certain segments of this project as thesis or class projects. One such segment could be a full virtual model of Tiburon that includes its manipulator arm motion, tool sleds, lights and cameras. Also, as a member of the VRML Review Board he can help accelerate adoptions of new conventions and standards that we identify as needed.

Gerry Hatcher is our interface to the Mapping project and will help supply the terrain and image data we need.

Paul Rogers and Tom O'reilly will have roles in helping with Java and communicating with distributed objects and data manager, especially in year two.

Please visit this project's web page at

http://www.mbari.org/~mccann/vrml/ROVvis_proposal/