Visualization of Earthquake Simulation Data

Çağatay Demiralp (PI), Jason Mallios (Co-PI), Terry Tullis (Collaborator)

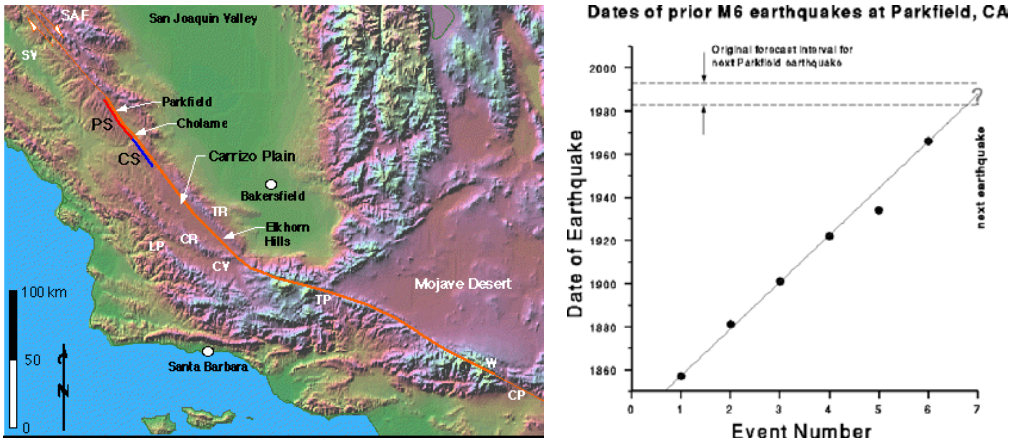
Abstract

Human and material costs of earthquakes are well known. Geologists use numerical simulations to understand the patterns in chronological behavior of earthquakes on faults, which can eventually help to predict earthquakes. These simulations result in massive, time varying data sets that are difficult to analyze. We propose to develop a tool to visualize a type of earthquake simulation data. It will help geologists understand the spatial and temporal relations and patterns of earthquakes on the fault plane that the simulation models. The visualization will be freely available to all researchers and extendable for using with other similar earthquake simulations.

1 Introduction

Earthquakes cost hundreds of billions of dollars and, more importantly, thousands of lives (average 10,000 deaths worldwide) each year around the globe [1]. The annualized long-term loss due to only US earthquakes is estimated 4.4 billion per year, and this figure appears to be rising rapidly [1]. Geologists study earthquake phenomena by running numerical simulations based on data collected from the field using numerical models. These simulations result in huge sets of numbers from which the mechanical behavior of faults may be understood. Analysis of such data can be time consuming and may not be very effective for further predictions. For example, seeing energy changes along a fault line on a 3D map is potentially more intuitive (ie. easier to see the relations with other fault lines, etc.) and less time consuming than by just analyzing the numbers. Visualization can help by integrating simulation data with useful visualization and interaction techniques allowing scientists to alter simulation parameters and annotate regions interactively.

Our collaborator, Professor Terry Tullis, is studying the physics of faults and earthquakes. Specifically, he is interested in the Parkfield section of the San Andreas fault (see Figure 1(a)). This section of the San Andreas fault has interesting characteristics to offer for scientists. It slips in magnitude 6 earthquakes every 20-30 years (see Figure 1(b)). Geologists hypothesize that creeping rock activity under the ground in this area triggers the big earthquakes. In this context, understanding the deep plate motions and surface strains caused by these motions at Parkfield becomes important. (For these reasons USGS (United States Geological Survey) has already installed various measuring instruments in the area, which provides vast data and, therefore, attracts more researchers). Professor Terry Tullis created a model (a numerical simulation) of earthquakes at Parkfield. His primary goal is to predict earthquakes by looking at patterns of micro-seismic activity. One of the goals is to use the simulations to help understand when small earthquakes grow into large ones and when they do not [2].



(a) (b)

Figure 1: (a) The Parkfield section on the San Andreas fault line. (b) Time sequence of magnitude 6 earthquakes ocured at Parkfield.

2 Aims

Our goal is to develop a tool to visualize the earthquake simulation data. The visualization will help geologists see the spatial and temporal relations and patterns in mechanical behavior of the Parkfield section of the San Andreas fault. This is important for testing the hypothesis that micro-seismic activity at Parkfield triggers bigger earthquakes in particular and developing models to predict earthquakes in general. The tool, integrated with the simulation method, can be used in study of any other faults. Further, since it will be built on a general framework, visualization of the data from similar simulations will be easy. The final tool, its source code and the simulation data will be made freely available to all researchers. This can be a means in disseminating the data and knowledge, and thereby bringing other scientists interest and help to the particular earthquake research problem. The simulation programs are now made freely available on the web, but without freely available visualization software to accompany this simulation code, the simulations code is much less valuable to the research community.

3 Data

The numerical simulation generates two different time varying 2D scalar data sets: One is the slip ratios on the fault plane and the other one is the strain values on the surface plane (see Figure 2). Both of these scalar fields are sampled on a hierarchical regular grid. The fault plane is the planar surface along which there is a slip during an earthquake. The slip on the fault causes changes in the strain on the surface on the earth where it is possible to make measurements in the real world. Since detection of theses changes in the strain is one of the more likely ways that the slip at depth might be detected, calculation of these changes has been done for this model. Because the rate of slip on the fault best characterizes any particular stage in the mode earthquake, the associated rate of strain at the earth's surface has been calculated [2].

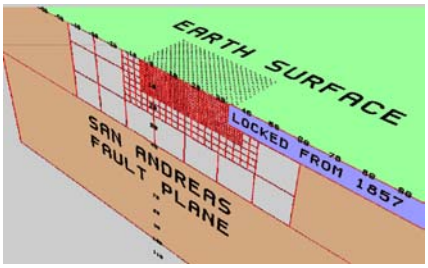


Figure 2: At time t_i we have slip ratio values for the fault plane and strain ratios for the surface plane, both are sampled on a hierarchical grid.

4 Methods

We define the problem as visualization of time varying scalar data. For visualizing scalar data we will use a combination of color mapping and iso-contouring, two well studied techniques. (see Figure 3(a)). For visualizing the temporal relations among the scalar data we will use iso-surface extraction and plane-with-memory techniques (see Figure 3(b)). Iso-surface extraction is an extension of iso-contouring method to 3D domain and can be effective for showing the temporal

relations at global level. We propose plane-with-memory technique to visualize the local temporal relations among 2D scalar fields. It maps a function of time to the opacity value of the 2D field plane with a blurring effect. We hypothesize that the technique will help to see the local temporal relations (see Figure 4).

We will develop an interaction allowing the user to play with visualization (ie. colormaps, iso-values) and simulation parameters while keeping the frame-rate at an acceptable level.

The project will be implemented using C++ and Open Inventor API. Open Inventor is a widely used, open source, scene-graph based graphics library, which fits well in our purpose of making the source code freely available.

(a) (b)

Figure 3: (a) shows the visualization of inter-bone distances using colormaping and iso-contouring techniques. (b) illustrates a simple iso-surface extraction.

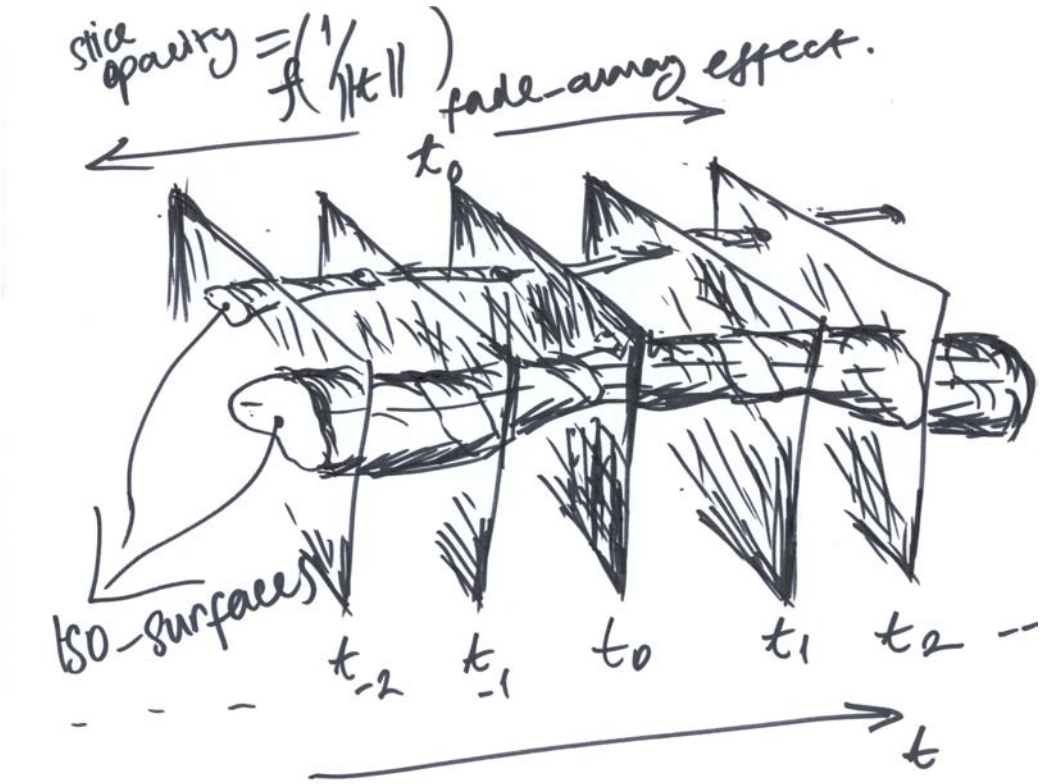


Figure 4: An illustration of plane-with-memory technique coincided with iso-surfaces.

5 Related Work

Visualization of scalar fields has been studied throughly. Color mapping, iso-contouring, volume rendering, iso-surface extraction are the few widely used techniques. Detailed discussion of these and other techniques can be found in many reference books [3].

We build on previous work in applying scientific visualization to the study of earthquakes. Weber et al. visualized displacement, acceleration, and strain that were measured during an earthquake simulation experiment in a geotechnical centrifuge. The work is similar to our proposed work in visualizing an earthquake related simulation data [4]. But their simulation is of a different kind; it focuses on the moment of earthquake and its effect on the ground (buildings) whereas our model simulates the motion of the plates under the ground and the accumulated strain created on the surface by this motion. Chopra et al. introduced a volume rendering technique, which runs both in an immersive environment (CAVE) and on a desktop, to visualize large scale ground motion simulation data [5]. The ground motion simulation data, velocity values, used in this work is similar to the data we will visualize in the our proposed work. In addition to velocity, we will also visualize surface strain values as mentioned before.

6 Timeline & Deliverables

Week 1&2: Initial data setup & software integration

Week 3: Color maps & iso-contours

Week 4: Plane-with-memory & iso-surfaces

Week 5: Improved interaction

Week 6: Final report which will include results from evaluation of the visualization by geologists.

Çağatay Demiralp will primarily work on the visualization part and Jason Mallios will work on the interaction part of the project. Terry Tullis will evaluate the usefulness of the work done at each step.

References

[1] National Research Council of The National Academies. *Living on an Active Earth: Perspectives on Earthquake Science*. The National Academies Press, 2003.

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[5] Prashant Chopra, Joerg Meyer, and Antonio Fernandez. Immersive volume visualization of seismic simulations: A case study of techniques invented and lessons learned. In *Proceedings of the conference on Visualization '02*, 2002.

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a. Professional Preparation

B.Sc. Computer Science, Ege University (2000)
Sc.M Computer Science, Brown University (2004)

b. Appointments

2002 - Present, Graduate Research Assistant, Brown University
2000 - 2002, Visiting Research Assistant, Brown University
5/1999 - 10/1999, Visiting Undergraduate Research Assistant, Brown University
11/1998 - 5/1999, Research Intern, Fraunhofer CRCG

c. Publications

i. Journal Publications

"In vivo measurement of contact areas and ligament lengths in the distal radioulnar joint" G. E. Marai, D. H. Laidlaw, C. Demiralp, S. Andrews, C. M. Grimm, and J. J. Crisco, IEEE Trans. On Biomedical Eng., in publication, 2003.

"Visualizing Diffusion Tensor MR Images Using Streamtubes and Streamsurfaces" S. Zhang, C. Demiralp, and D. H. Laidlaw, IEEE TVCG, Vol. 9, No. 4, October-December 2003.

ii.Conference Publications

"Subjective Usefulness of CAVE and Fish Tank VR Display Systems for a Scientific Visualization Application", C. Demiralp, D. H. Laidlaw, C. Jackson, D. Keefe, and S. Zhang, poster abstract, IEEE Visualization 2003, Seattle, October 2003.

"Contact Areas and Ligament Lengths are Abnormal in Patients with Malunited Distal Radius Fracture Despite Normal Radioulnar Kinematics" G. E. Marai, D. H. Laidlaw, C. Demiralp, C. Grimm, J. J. Crisco, D. C. Moore, and E. Akelman, IV World Congress of Biomechanics, Calgary, August 2002.

"Modeling and Visualization of Inter-Bone Distances in Joints" C. Demiralp, G. E. Marai, S. Andrews, D. H. Laidlaw, J. J. Crisco C. Grimm, IEEE Visualization 2001, San Diego, October 2001.(pdf)

"Visualizing Diffusion Tensor Volume Differences" M. J. da Silva, S. Zhang, C. Demiralp, and D. H. Laidlaw , IEEE Visualization 2001, San Diego, October 2001.

"Visualizing the differences between diffusion tensor volume images" Marco DaSilva, Song Zhang, Cagatay Demiralp, and David H. Laidlaw. In Proceedings ISMRM Workshop in Diffusion MRI: Biophysical Issues, pages 237-238, March 2001.

"An Immersive Virtual Environment for DT-MRI Volume Visualization Applications: A Case Study" S. Zhang, C. Demiralp, D.F.Keefe, M. J. da Silva, D. H. Laidlaw, B. D. Greenberg, P.J. Basser, E.A. Chiocca,C. Pierpaoli T.S. Deisboeck, IEEE Visualization 2001, San Diego, October 2001.

"Toward Application of Virtual Reality to Visualization of DT-MRI Volumes" S. Zhang, C. Demiralp, D.F.Keefe, M. J. da Silva, D. H. Laidlaw, B. D. Greenberg, P.J. Basser, E.A. Chiocca,C. Pierpaoli, T.S. Deisboeck, MICCAI 2001

"Interactive Visualization of 3D Carpal Kinematics and Bony Anatomy" J. J. Crisco, C. Demiralp, D. H. Laidlaw, A-P. C. Weiss, E. Akelman, and S. W. Wolfe, Scientific Exhibition, ASSH 56th Annual Meeting, Baltimore, MD, October 2001 (awarded for "Best Scientific Content" and "Best Scientific Layout and Presentation")

"Usability Evaluation of a Set of Cognitive Tool Software by Teacher Educators" E. Orhun, C. Demiralp, 2nd International Conference on Technology in Teaching and Learning in Higher Education, June 2001, Samos Island, Greece

d. Synergistic Activities

(1) As the chair of IEEE Ege University Student Branch, organized talks, seminars and a technical visit to the Netherlands.

(2) Organized one-day Virtual Reality activity for the high school students attending Brown Summer School from Saudi Arabia.

e. Collaborators

David H. Laidlaw, Brown, Terry Tullis, Brown, Song Zhang, Brown, Liz Marai, Brown, Stuart Andrews, Brown, J. J. Crisco, Brown, Daniel Keefe, Brown, Cullen Jackson, Brown, Jurgen Schulze, Brown, Dean Turner, Edinburgh.

f. Advisors

Professor Emrah Orhun, Ege University
John D. Coleman, Fraunhofer CRCG
Professor David H. Laidlaw, Brown University

Name: Jason Mallios
Year: Graduate (Masters, 1st year)
E-mail: jmallios@cs.brown.edu

Phone(s): (401) 632-0847 home; x7683 office

Want to learn:

I'm trying to bridge the gap between Theory / Algorithms / Complexity and Graphics / HCI / modelling. Technically, these are different fields, but I seem to move between them pretty well. I'd like to explore both realms and find my fit.

I'm multifaceted by nature, and my academic pursuits run the gamut of English, Philosophy, Creative Writing, Art, Anthropology and Computer Science. Generally, I'd like to learn how to conjoin these interests.

Other goals for class:

I'm not financially supported at Brown, so I need to hit the fellowship and grant trail pretty hard. This class seems the perfect accoutrement to this end.

Role you would like to play in a project and skills you bring:

I consider myself a passable writer and adept communicator. Hopefully, this will lend itself to the, "big picture," aspects of a project. I've worked in design, both print and Web, for several years, and can discourse on information depiction and navigation in a very human sense. The style of research I prefer is slow but thorough.

Lastly, I love to program and model. My only past experiences where the two have met are C++ / OpenGL still lifes and Java Applet demos of sorting algorithms. I think I'll be beneficial in a tools and coding role. However, I understand this to be a relatively slight component of the production process.

Relevant math classes taken (calculus, linear algebra, numerical methods, signal processing, ode's, pde's, etc.):

Differential and Integral Calculus
Computer Graphics (transformations, vectors, matrices)
Discrete and Combinatorial Mathematics
Statistics & Probability

Relevant science classes taken:

Solar System and Interstellar Astronomy
Cultural and Physical Anthropology, Archaeology
Some basic Biology, Psychology, and Sociology

Other relevant classes or experience:

http://members.cox.net/jmallios/

From: "Terry E. Tullis" <Terry_Tullis@brown.edu>
To: "Cagatay Demiralp" <cad>
Cc: "Terry E. Tullis" <Terry_Tullis@brown.edu>,
"David Laidlaw" <dhl>
Subject: RE: scientific visualization class project

Dear Cagatay,

I really enjoyed meeting with you yesterday and discussing my project / your potential project. You strike me as the ideal person to work with on this and I'm
hoping that you decide this project is the one you choose. The idea that you could
make something that would allow anyone to use it for viewing these models is very
interesting and important to me. If there is also some way to get it working remotely over the web so it could be run on remote machines and then viewed here or somewhere else, then that would be even better!

Cheers,
Terry

Visualization of Platelets in Small Blood Vessels

Abstract

Platelet aggregation is important for closing the minute ruptures in small blood vessels that occur hundreds of times daily, but may also lead to arterial occlusion in the setting of atherosclerosis and trigger disease such as myocardial infarction. The goal of this project is to develop an interactive system using immersive environment to visualize the blood platelets in the flow through small blood vessels.

Participants
PI: I. Pivkin
Co-PI: N. Yang, D. Grollman

Consultants
D.H. Laidlaw
P.D. Richardson

Introduction

Platelets are blood cells 2 to 4 microns in diameter with a normal concentration in blood of around 150,000 to 350,000 cells per cubic millimeter. Platelet aggregation is important for closing the minute ruptures in small blood vessels that occur hundreds of times daily, but may also lead to arterial occlusion in the setting of atherosclerosis and trigger disease such as myocardial infarction. Platelet aggregation involves platelet activation due to vascular injury, cell-cell interactions, platelet-vessel walls and platelet-thrombus interactions[1].

I. Pivkin, P.D. Richardson and G.E. Karniadakis have employed the Force Coupling Method[2] to model platelets as spherical force envelopes, instead of solid spheres. Appropriate forces are added to the simulations in order to prevent cells from overlapping or penetrating the walls. Additional forces are added to simulate the adhesion of activated platelets to the vessel walls or other platelets. It is possible to perform the simulations with thousands of platelets.

Goals

The primary goal of the project is to visualize the three dimensional results of simulations with hundreds or thousands of platelets. We want to examine an interaction of platelets with vessel walls and other platelets. In simulations with platelet aggregation, we will be interested in the visualization of aggregate formation, its three dimensional structure and interaction of platelets with the aggregate.

In order to do this, we will develop a visualization system for use in the CAVE.

Significance of work

Currently the simulation results are visualized using commercially available software Tecplot from Amtec Engineering, Inc. Tecplot can display large number of platelets on a standard computer monitor. However, due to the three dimensionality of the data, it may be difficult to understand the location of platelets in space, their interactions and structure of platelet aggregate (Figure 1). An additional examination of the results is often necessary.

The development of the visualization system using an immersive environment will help us to analyze the simulation results. Better understanding of the process of platelet aggregation can potentially lead to the methods for prediction of critical locations in vascular tree. In addition, it may facilitate the improvement of medical devices, such as artificial heart valves and blood pumps.

Related work

This project is based on research work I. Pivkin is doing as a Ph.D. student in the Division of Applied Mathematics. He has been working with P.D. Richardson, D.H. Laidlaw and G.E. Karniadakis on simulation of blood flow in arteries,

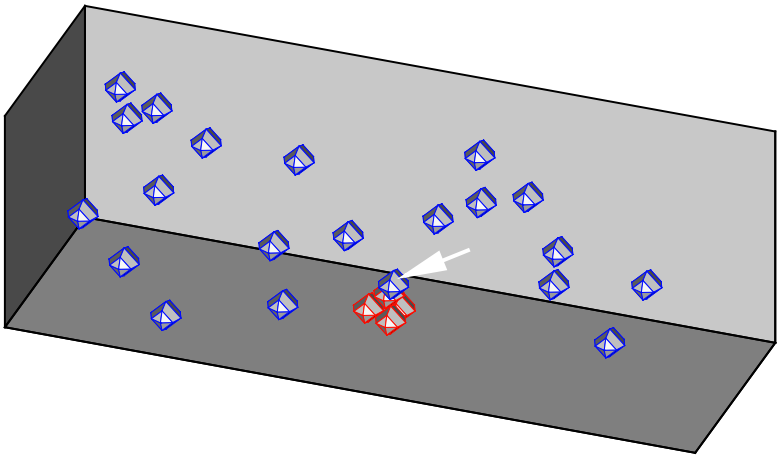

Figure 1: An example of visualization in Tecplot. Notice that marked platelet does not interact with the aggregated platelets. The platelet aggregate is far behind the marked platelet.

particularly, in coronary arteries, subject to motion and curvature variation as they lie on the heart surface[3]. Some of the results were used as test cases in the development of visualization tools in the CAVE[4]. Adding platelets to the blood flow is a natural continuation of carried research. Previously developed visualization tools, such as "artery" demo in the CAVE[4], will be used as a basis for the proposed project.

Visualization details

The simulation data consist of the following. At every simulation time step, for each platelet, its biological state, radius, mass, position in space and velocity are given.

As mentioned earlier the proposed visualization tool will be built using existing "artery" demo, however some modifications will be necessary. Although visualization of pathlines is the main component of the "artery" demo, we will not be interested in visualization of pathlines, because platelets alone are good indicators of flow features. The platelet simulations are not periodic in time and therefore continues looping through the data seems to be inappropriate. A user should have an ability to move forward and backward in time. In addition, the user should be able to control the visualization speed. This is important, because individual platelet interactions happen on a small time scales comparing to the total simulation time. The user interface will be modified to provide mentioned above.

Some preprocessing of the simulation data will be necessary as well. Continues trajectory of each platelet will be constructed using positions and velocities at discrete time moments. It will be accomplished by smooth interpolation,

probably using splines. This will allow to approximate the platelet positions at any time moment.

The platelets will be visualized as tessellated spheres. We will use different colors to show different biological states of platelets. For large number of platelets occlusion can be a problem. Making platelets semi-transparent may be a solution. We may also try to visualize part of the platelets (probably biologically inactive) in a simplified way, similar to tracers in the "artery" demo[4].

We will not limit ourselves with the things listed above. As time permits, we will experiment with the visualization and try to find an effective way to visualize the data.

Work Plan

The following plan is proposed:
1. Week 1: High level coding design, preparation of simulation results for visualization.
2. Week 2-3: Modification of user interface, visualization of platelets.
3. Week 4-5: Testing and improvement of visualization tool.
4. Week 6: Writing final abstract and preparing presentation.

Facilities

The project will be developed in the CAVE at Brown University.

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[2] M.R. Maxey and B.K. Patel. Localized force representation for particles sedimenting in stokes flow. *Int. J. Multiphase Flow*, 9:1603, 2001.

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CV for I.V. Pivkin

Personal

Name: Igor V. Pivkin
E-Mail: piv@cfm.brown.edu

Education

Master of Science degree in Applied Mathematics, May 2002
Brown University, USA

Master of Science degree in Mathematics, June 1999
Novosibirsk State University, Russia

Bachelor of Science degree in Mathematics, June 1997
Novosibirsk State University, Russia

Related skills and experience

During my graduate studies, I have participated in many computational fluid dynamics projects. I have taken classes from medical school and have a basic background in biology. I will work on producing physiologically relevant results for visualization, as well as actively participate in the development of the software.

CV for N. Yang

Personal

Name: Nicholas Yang
E-Mail: Nicholas_Yang@brown.edu

Education

Bachelor of Science degree in Computer Science, May 2003
Brown University, USA

Related skills and experience

I have worked 3 summers in my undergraduate years at college, programming for DYS Analytics, Pegasystems, and the Brown CS Graphics Group. I have a strong background in C/C++ and Java programming and experience with working in a CAVE environment. I have taken courses in Computer Graphics and Computational Biology. I have a basic biology background.

CV for D. Grollman

Personal

Name: Daniel Grollman
E-Mail: dang@cs.brown.edu

Education

Bachelor of Science: Electrical Engineering and Computer Science, 2003
Yale University, USA

Related skills and experience

Programming Languages: C, C++, BASIC, PowerBASIC/DLL, Java, Haskell functional programming, Perl, Assembly.
Experienced in developing and designing protocols and experiments for use in medical, electrical and robotic laboratories

Collaborator Support

Peter Richardson
Division of Engineering and Department of Pharmacology, Physiology and Biotechnology

Date: Mon, 29 Sep 2003 15:16:45 -0400
From: Peter Richardson
To: dhl@cs.brown.edu
Cc: piv@cfm.brown.edu
Subject: Igor's project

David,

I will be happy to be consultant for the project on visualization of blood platelets in flow through small blood vessels, in the visualization course Igor Pivkin is taking with you this semester. We have already started discussions about this. Peter

David Laidlaw
Department of Computer Science

Date: Mon, 29 Sep 2003 16:27:04 -0400
From: David Laidlaw
To: piv@cfm.brown.edu
Subject: letter of collaboration

Hi Igor -

I am delighted to be able to consult on your project to visualize platelets in arterial blood flow simulations. I will bring my visualization expertise and my understanding of the issues in hemodynamics to the problem. I expect that we'll be able to make some headway during the project this semester.
Best,

-David Laidlaw

Virtual Reality Visualization Techniques for a 4-Dimensional Environment

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October 13, 2003

Abstract

Visualization of higher dimensional environments using immersive VR has been largely uncommon in the world of scientific visualization. The goal of the proposed research is to investigate the effectiveness of visualizing and interacting with a 4D environment in a virtual realistic context.

1 Introduction

It is relatively easy to create cognitive maps of lower dimensional entities, such as 0D, 1D, 2D, or 3D objects and environments. Take a roadmap, for example. We can point out distinct cities, towns, and landmarks, which are all 0D points. To travel from one point to the next, we move in several 1D lines. The locations of these points are described using a latitude-longitude coordinate system, which is 2D. Some maps have contour lines that show ground elevation, which is 3D. How can we portray 4D objects and spaces? We might try thinking of 4D contour lines on a 3D map, as was done in [4]. But representation of higher dimensional objects, let alone higher dimensional environments, has never been an easy task. We live in a 3D world where our spatial knowledge prevents us from gaining a more natural intuition of higher dimensional entities.

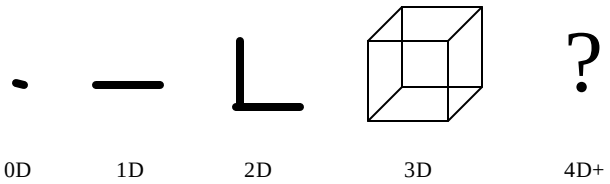

Figure 1.1. We can perceive 0D to 3D intuitively. How do we represent 4D and higher? Our goal is to create a tool that will help users gain a better intuition of the 4th spatial dimension.

Notice that a roadmap is 2D, and much information is lost in projecting 3D onto 2D. For instance, the 3D cube in Figure 1.1 is a 2D projection of a 3D object. How do we know that this is an actual 3D object and not just 2D lines that *look* like a 3D object? If we wish to continue using 2D projections to understand higher dimensional entities, it will become increasingly difficult because there are two or more levels of dimensional information that will be lost. Through 2D projections, we can only gain a sense of the underlying structure [1], but certainly not the full picture. Thus, we propose using a virtual 3D environment to create a deeper and more solid foundation for visualizing the 4^{th} dimension.

2 Problem Statement

There is planned work for implementing a 4D object handler in a CAVE environment [6], but in the proposed project, we intend to place users directly *inside* 4D objects and not just enable them to manipulate 4D objects from the outside. Conventional methods focus on the *rotation* of 4D objects as being the driving tool behind understanding 4D complexity [3]. We want the user to experience 4D complexity in a first-person setting. Being inside a 4D object is analogous to being in a 4D world.

We propose a multi-disciplinary, virtual-reality-based research project to seek out and develop tools and techniques that will enable users to effectively interact with and understand 4D environments. The project will involve extensive collaboration between Cognitive Science, for designing and evaluating different approaches and methods, Computer Science for project implementation and tool development, and Mathematics, for consulting in 4D models and theory. Our hope is to construct a fully functional set of tools for 4D navigation. Ideally, the work completed in this project will eventually be expandable to aid the visualization of even higher dimensional environments as well.

3 Goals

During this semester, we expect to complete an infrastructure for the user interface, a basic 4D world for simple navigation, and preliminary tests to evaluate plausibility of continued research. The target goal is to build a Euclidian 4 dimensional space so that moving in the *w*-th dimension is perceived in the same way as moving in each of the other dimensions. By understanding and interacting with the 4D variable, we hope to create a deeper and more solid foundation for visualizing the 4th dimension. The approach we will be taking is similar to [8], where 3D visualization is constrained to 2D controllers; we are merely taking it one dimension higher. It is also analogous to "walking the data," similar to the method for

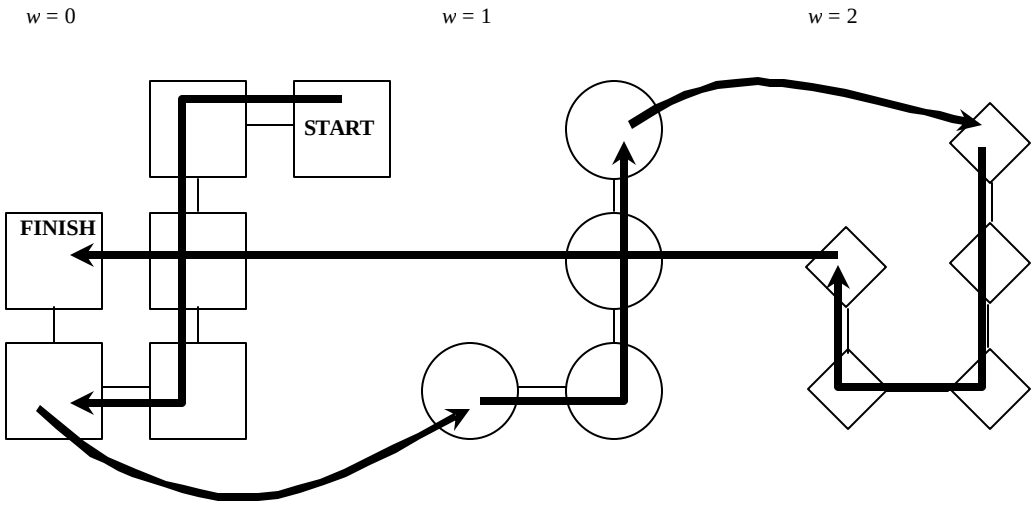

Figure 3.1. An example of navigating in a 4D world where *w* is represented by room shape. Note that to get from Start to Finish, the user does not have to take the direct route, staying in $w = 0$. Instead, the user changes the 4D variable, travels in $w = \{1, 2\}$, and then returns to the destination point back in $w = 0$. This is a 2D map of a 4D world, meaning there is loss of information; we are missing movement along the *z* axis. A VR-environment with a 3D map would make the complete visualization easier to understand. Also note that the paths of the 3D maps of each *w* value do not necessarily look alike, much like taking 2D slices of an irregularly shaped 3D object. In the proposed work, we will be taking 3D "slices" of a 4D world (object), and we hope the use of VR will facilitate this understanding.

walking complex mathematical manifolds in [7].

The main goals of this project are: (1) to design, implement, and develop a complete 4D world in an immersive VR-environment, (2) to examine several possible user interfaces, and (3) to evaluate and discuss the most effective techniques for visualization of a 4th spatial dimension. We intend to represent the 4D world as a series of hallways and corridors, much like the 4D virtual environment project conducted at Indiana University [2], but our representation will be different; in addition to moving along the conventional *x*, *y*, and *z* axes, we will introduce a new method for moving in the fourth dimension, along the *w* axis. It is not clear exactly how 4D movement can be quantified or measured. Since we are physically limited to moving in only *x*, *y*, and *z* directions, we may use a method such as measuring the distance between the user's hands to determine the value of the *w* variable. The method will hopefully become a metaphor for what 4D movement really is. As the value of *w* changes, the properties of the environment will change in a regular way (i.e. changing the shape of the room, as shown in Figure 3.1) to reflect the new *w* value. After gaining some intuition for how we can move about in 4D, we hope to have a better understanding of how 4D movement should be quantified and conceptualized.

The project will contain an experimentation portion where the implemented tool will be used by several people. They will be given tasks such as finding hidden objects or reaching a destination point in the 4D world. In terms of Cognitive Science, we wish to determine if people are capable of navigating around in a purely 4D context, essentially navigating within a 4D object, forcing them to learn from a 3D perspective. Our hope is that users will be able to gain a more intuitive feel for higher dimensional visualizations. Based on the success rate of the participants, we will conclude whether this is true or not.

The value of virtual environments is gradually beginning to establish itself among people of the scientific visualization community. We hope to exemplify some of the benefits provided by using virtual environments, particularly in topics about spatial dimensionality.

4 Significance and Motivation

Effectively visualizing higher dimensional space has been a long-time desire of many people, especially mathematicians and computer graphics specialists [2]. Our hope for the proposed work is that being in 4D objects will enable users to gain a more immediate intuition and understanding of the nature of 4D data. Through this understanding users will interact with 4D data more efficiently and effectively.

Higher dimensional entities are frequently described, manipulated, and discussed in mathematical functions, equations, surfaces, and objects. Math is found in all sorts of places in our world, especially in nature: fractals, waves, geometry, etc. Equations and formulas can represent many 3D models using third degree variables. What is represented by higher degree equations, though? Higher dimensional entities are commonly described and used, but we only have a partial understanding of them because we do not fully understand their true nature. We lack effective tools for visualization.

In terms of physics, higher dimensional environments are generally harder to understand from lower dimensions. It is difficult to understand in what "direction" or in what manner that additional variables in dimensions greater than 3D are actually represented in our world because such factors are invisible to the human eye. Beyond 3D, the limitation of our intuitional spatial knowledge, many people often begin to lose an accurate portrayal of dimensionality. By using interactive techniques and visualization, we will gain a much better intuition of higher dimensional environments. Similar to how we can gain knowledge of 3D space from 2D maps, we intend to gain knowledge and learn about 4D space using 3D maps in a virtual environment. Finding a suitable method for visualizing 4D space is an essential first step to determining exactly how 4D and higher dimensions exist in this world.

Higher dimensional environments do not exist only in a purely mathematical or physics context. For instance, creating 4D viewing interfaces, as an alternative method of manipulating and handling objects, is also a viable application [6]. The World Wide Web is a prime example of a multi-dimensional entity. If the Internet was limited to 4D data, our project would essentially aim to put people directly "into" the Internet and see how well they navigate in the data and 4D space. Will being in the data help users interact with and understand the different parts of it? The proposed work intends to answer this question.

The broader impact of the proposed project lies in discovering new realms of dimensional space for further research and exploration. This area has been rather untouched and sometimes termed as something "beyond our world." We have long pondered the question of exactly what dimension we live in and how many we are capable of interacting with [2]. We might very well already be in the 4^{th} dimension but just do not know how to work with the 4D *w* variable. We hope to finally begin to be able to solve the question of exactly what dimensional space is, how many dimensions there are, and why and how they exist in our world.

5 Facilities

We will utilize the 40' x40' VENLab (Virtual Environment Navigation Laboratory) VR-environment located in the Department of Cognitive Science at Brown University. Inside the VENLab are various devices for user interaction including a radio mouse with a trackball and 3 buttons, an additional tracking device with two buttons (currently mounted to a glove), and a stylus for pointing in VR. VENLab machines are equipped with recent SGI technology. The proposed work will be the first 4D visualization project to use a VR-environment of this size.

Models are currently designed in 3D-Studio Max and ported to the VR system using World Toolkit (WTK). The programming language of choice is C++.

Figure 5.1.
The VENLab is a 40'x40' virtual environment where the user is free to walk around and explore (left).

The appearance, as seen by the user, of a virtual world in the VENLab (right).

6 Principal Investigators and Collaborators

Nicholas C. Yang (PI)	Overseer of project, programmer and developer
Igor Pivkin (Co-PI)	Programmer and developer; interface devices
David Eigen (Co-PI)	Programmer, developer, and math theory; world design
Daniel B. Rothman (Collaborator)	Consultant for theory and approach
William H. Warren, Ph.D. (Collaborator)	Main consultant for interface design and evaluation
Thomas F. Banchoff, Ph.D. (Collaborator)	Main consultant for conceptualization of 4D space

7 Research Plan

Week 1: Review and refine data representation, algorithm, and user interface; begin coding.
Week 2: Become familiar with VENLab demos; begin VR coding.
Week 3: Complete first version of code framework; begin gathering users for evaluation
Week 4: Begin testing (4D maze and/or treasure hunt). Debug code.
Week 5: Complete user-testing.
Week 6: Evaluate and discuss results. Plan for future work and development.

8 Related Work

The topic of researching and understanding higher dimensional environments is not new, and much work has already been done [5]. This project aims to improve on the techniques and approaches used in past work, with focus on using the unique VENLab for a VR-environment.

Two of the more prominent papers of past work that has been done are Michael D'Zmura's paper on "Virtual Environments with Four or More Spatial Dimensions" [2] and Gregory Seyranian's paper on "Search and Navigation in Environments with Four Spatial Dimensions" [10]. D'Zmura's and Seyranian's works, however, were based more off of a series of 2D maps, as opposed to a true 4D world. The type of world described in these works can be drawn out on paper without much difficulty, thus, not necessarily requiring the use of an immersive VR-environment. But as mentioned in the introduction, much information is not present in a 2D projection of higher dimensional entities. This implies that the data used in D'Zmura's and Seyranian's cover only data sets where information is not lost in the projection from 4D to 3D. In a true 4D world, users would not necessarily be able to discover on their own what is being represented in the 4D world unless they have the maps to study ahead of time. Also, the interface in the proposed work aims to be more intuitive than taking elevators to get between different *w* axis variables.

Another past project is Prabhat's Master's project on "Comparative Evaluation of Desktop and Cave Environments for Learning Hypercube Rotations" at Brown University. In this project, a specific 4D object, a hypercube, was modeled. Prabhat found that user interfaces were significantly easier on desktop but visualization was harder; in the CAVE, the conditions were vice versa [9]. This emphasizes the importance of user interfaces as well as the usefulness of using a virtual environment to visualize 4D.

References

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[5] Hanson A. and Heng, P. (1992). *Illuminating the Fourth Dimension.* IEEE Computer Graphics and Applications, 12, 4, 54-62.

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[9] Prabhat (2001). *Comparative Evaluation of Desktop and Cave Environments for Learning Hypercube Rotations.* Brown University, unpublished.

[10] Seyranian, Gregory D. and Michael D' Zmura (2001). *Search and Navigation in Environments with Four Spatial Dimensions.* University of California, Irvine.

Curriculum Vitae for Nicholas C. Yang

Name: Nicholas C. Yang
Email: nyang@brown.edu

Education:
- Bachelor of Science in Computer Science, May 2003, Brown University, Providence, USA

Research and/or Professional Experience:
- Software Engineer, Brown University Computer Science Graphics Group, Summer 2003
- Software Engineer, Pegasystems, Summer 2001
- Software Engineer, DYS Analytics, Summer 2000
- Webmaster, YMAA Publication Center, Summer 1997

Relevant Skills:
- Strong coding experience (C/C++)
- Experience working in CAVE environment
- Experience with user interface design in CAVE
- Computer graphics knowledge

Curriculum Vitae for Igor Pivkin

Name: Igor Pivkin
Email: piv@cs.brown.edu

Education:
- Master of Science in Applied Mathematics, May 2002, Brown University, USA
- Master of Science in Mathematics, June 1999, Novosibirsk State University, Russia
- Bachelor of Science in Mathematics, June 1997, Novosibirsk State University, Russia

Research and/or Professional Experience:
- During my graduate studies, I developed my programming skills working on moderately-sized scientific programs. I have experience in C/C++. I have a strong background in Pure and Applied Mathematics and some Computer Graphics knowledge.

Relevant Skills:
- Coding experience (C/C++)
- Strong mathematical background
- Computer graphics knowledge
- Experience working in CAVE environment

Curriculum Vitae for David Eigen

Name: David Eigen
Email: deigen@brown.edu

Education:
- Bachelor of Science in Computer Science and Mathematics, May 2003, Brown University, USA

Research and/or Professional Experience:
- Ongoing work with Professor Thomas Banchoff at Brown University, since Summer 2000, developing software tools for creating interactive visual demonstrations, mostly for differential geometry and calculus. This software is currently used by both students and instructors in differential geometry, calculus, linear algebra, geometry and analysis classes at Brown.
- Teaching Assistant, CS 224 (Interactive Computer Graphics), Spring 2003
- Teaching Assistant, CS 173 (Programming Languages), Fall 2002

Relevant Skills:
- Strong coding experience (C/C++)
- Strong mathematical background
- Computer graphics knowledge

Collaborator Support

Name: Daniel B. Rothman
Email: Daniel_B_Rothman@brown.edu

To whom it may concern,

I, Daniel Rothman, will be working in collaboration with Professor Bill Warren and some student(s) from the CS237 class should this project be approved. This project is my creative vision born from my honors thesis, and I would be delighted to provide whatever design support is needed to help the programmers implement the idea. I will definitely be around working on my thesis so I will be able to provide direction all along the way. This will be an awesome project, almost entirely unique since no one has done anything even close. I am really looking forward to the birth of 4D.

~Daniel Rothman

Name: William H. Warren
Email: Bill_Warren@brown.edu

Hi Nick:

I support the 4D World project, and would be happy to provide advice on its design and implementation in the VENLab.

-- Bill

William H. Warren, Professor and Chair
Dept. of Cognitive & Linguistic Sciences
Brown University, Box 1978
Providence, RI 02912
(401)863-3980 ofc, 863-2255 FAX
Bill_Warren@brown.edu

Name: Thomas F. Banchoff
Email: Thomas_Banchoff@brown.edu

Dear Nicholas Yang,

Definitely I support the project you have outlined and I will be happy to act as a collaborator, specifically on mathematical aspects of the problems you will be considering. The challenge of visualizing shapes like functions graphs is something we handle quite well when it comes to inferring three-dimensional information from pictures of graphs of functions of two variables projected onto a screen. It will be good to explore the comparable project, up one dimensional notch. I look forward to talking with you again and to seeing the material you are considering with Professor Warren.

Prof. Banchoff

An Application for the Assembly of Virtual Pots Using an Intuitive Interface and Probability-Computing Software

Abstract:

We propose to create a visualization tool for the assembly of virtual pottery fragments called potsherds from their computed tomography images, or CAT scans. The tool will utilize a user interface allowing the user to select and pair fragments together aided by software developed at Brown University which computes likely pairs. The goal is to combine the unique talents of computer and user to aid the archaeologist in visualizing assembled shapes inherent to fragments.

Collaborators:

- Principal Investigator: Jason Mallios
- Scientific Visualization Group: Vadim Slavin, Cagatay Demiralp
- Consultant: Stuart Andrews
- Archaeologist: Katharina Galor, PhD

Project Description:

The purpose of this project is to incorporate user-interface into computational reconstruction of 3D representations of pottery found at archaeological sites. Although other groups like the Vienna University of Technology and the IEEE/CVPR workgroup are working on aspects of the problem, Brown University is uniquely poised to tackle it. We have access to the archaeological ceramic fragments of the Great Temple site in Petra, Jordan, we sponsor the Laboratory for Engineering Man-machine Systems (who is experimenting with curve-matching of fragment breaks), and the Computer Science department has developed a pair-matching software application to computationally evaluate pairs of fragments.

The problem of matching 3D representations of pottery fragments, known as potsherds or sherds in the field of archaeology, is being investigated from a variety of perspectives, but current research does not include a mingling of archaeologist and software. Our goal is to combine the skill of the human user, who is relatively good at matching pairs, and the computational and graphic brawn of the machine, which can compute probabilities and complex linear algebraic comparisons and represent 3-dimensional objects virtually. In doing so, we want to facilitate the grit and glue approach typically used in assembly. Our purpose is to optimize the process of reconstruction, allowing more fragments to be reassembled and giving the archaeologist a more comprehensive understanding of the data at hand.

To accomplish this, we intend to use a fishtank virtual environment, which is a 3D space depicted by an ordinary computer screen in which all the fragments, "float," in the background while the selected pair are brought to the foreground and shifted into different configurations computed by the software. The user selects the best pairing and continues through each remaining fragment with a conglomerate view of the assembled pieces to guide her.

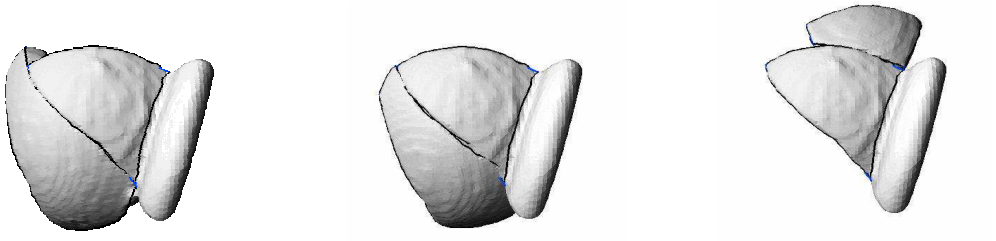


Figure 1: Different configurations of several potsherds. The user can pick the best fit. If, as in this case, all pairs seem likely, the software will provide a probability of each match and a conglomerate view of the assembled pot, with which the user can make further judgements. Notice how texture is a relatively simple way to compare for the human, but it is not so for the computer.

The visualization aspect of this project is two-fold. Primarily, we want to allow the archaeologist to toggle through different configurations of potsherd pairs in a quick and intuitive manner. Our hypothesis for this short-term aspect of the project is that the interface of human and software will allow a faster and more insightful reconstruction of potsherds than current processes. Secondly, if we achieve our primary goal, we hope future projects will extrapolate our process to a mass scale, allowing a larger and more comprehensive visualization of potsherd data through it's assembled shapes.

Archaeologists will, hopefully, be able to look at fragmentary artifacts as a collaborative whole. In other words, we hope they can see meaningful shapes instead of fragments in their data, and consequently, the site from which the sherds were obtained will elicit more understanding.

Our project is interdisplinary, joining the realms of Computer Science, Scientific Visualization, Software Engineering and Graphic Art (in that the expression of 3D data and user-interface is a creative process deeply embedded in navigation and intuitive representation). Our team is a competent group of individuals from each of these disciplines. Jason Mallios, Cagatay Demiralp and Vadim Slavin are computer graphics programmers and developers with significant experience in C++, the language of the software used to compute likely pairs. Jason brings years of graphic art experience to the table, Cagatay has worked with scientific visualization of multi-valued data before, and Vadim is established as a software developer. Stuart Andrews is the author of the pairing software and has agreed to consult us in its use. Katharina Galor is an accomplished archaeologist with many years of fieldwork.

The scientific merit of virtual sherd reconstruction with user-interface should have short- and long-range manifestations. To begin with, we expect the archaeologist to consider a smaller set of sherd pairings with the software's help
and greatly optimize the assembly process. If we can show that the conjoining of human and machine more quickly or more correctly perform the task, then we have successfully built a visualization tool whose significance can then be extrapolated to large-scale usage. It is in the large-scale experimentation of future projects that we hope to see long-range manifestations. Specifically, we hope to see benefit in the accumulation of reconstruction data, so archaeologists can view collections of shapes instead of collections of fragments.

The novelty in our approach is made clear by other research in this arena. Several systems exist for reconstructing or imaging artifacts, but none that we found allow assembly with an interface. It is the melding of archaeologist and software that makes our project unique, and it is through this tryst we hope to, first, provide optimization of a current problem, and second, pave the way for a more informed, more comprehensive perspective of archaeological data.

Six-Week Plan:

Week 1 beginning 10/20/03: During this week, we will create the fishtank space and incorporate the isosurface shapes of the potsherds created by Stuart Andrews.

Week 2 beginning 10/27/03: We will build the interface, allowing the selection of two background shapes to bring the pair forward.

Week 3 - 4 beginning 11/3/03: We will incorporate the software developed by Stuart Andrews, so the likely configurations of a pair can be, "tabbed," through. We will build restrictions into the system that preclude the assembly of unnecessary pairs that might confuse or negate associations between sherds already made.

Week 5 - 6 beginning 11/17/03: For these weeks, we will allow the archaeologist to use the software, evaluate its usefulness and make suggestions. We will refine it, if possible, and construct our research abstract and demo for the Brown University SciVis Project Funding Agency.

Bibliography:

Stuart Andrews and David H. Laidlaw. Toward a framework for assembling broken pottery vessels. In Proceedings of the 18th National Conference on Artificial Intelligence, pages 945-946, July/August 2002.

David B. Cooper, Andrew Willis, Stuart Andrews, Jill Baker, Yan Cao, Dongjin Han, Kongbin Kang, Weixin Kong, Frederic Leymarie, Xavier Orriols, Senem Velipasalar, Eileen Vote, Martha Joukowsky, Benjamin B. Kimia, David H. Laidlaw, and David Mumford. Bayesian virtual pot-assembly from fragments as problems in perceptual-grouping and geometric-learning. In Proceedings of ICPR, volume 3, pages 30297-30302, 2002.

David B. Cooper, Andrew Willis, Stuart Andrews, Jill Baker, Yan Cao, Dongjin Han, Kongbin Kang, Weixin Kong, Frederic Leymarie, Xavier Orriols, Eileen Vote, Martha Joukowsky, Benjamin B. Kimia, David H. Laidlaw, David Mumford, and Senem Velipasalar. Assembling virtual pots from 3D measurements of their fragments. In Proceedings of VAST, 2001.

Georgios Papaioannou, Evaggelia-Aggeliki Karabassi, Theoharis Theoharis. Virtual Archaeologist: Assembling the Past. IEEE Computer Graphics and Applications, pp53-59, March/April 2001.

Jiang Yu Zheng, Zhong Li Zhang. Virtual Recovery of Excavated Relics. IEEE Computer Graphics and Applications, pp6-11, May/June, 1999.

Other groups performing similar research:
Pattern Recognition and Image Processing Group, Vienna University of Technology. http://www.prip.tuwien.ac.at/.

Laboratory for Engineering Man-machine Systems, Brown University

IEEE/CVPR Workshop on Applications of Computer Vision in Archaeology

Intent to Collaborate:

Written intent to collaborate are reproduced here only for those collaborators outside of the Scientific Visualization Group.

Stuart Andrews

I will make myself available to answer technical questions, to offer advice on design decisions etc for two hours a week until December. I can offer some help with basic linear algebra, 3D geometry, probability and complexity theory. However, I believe that my most valuable contribution, as important as the general framework, will come out of sharing my in-depth and hands-on experience working on this challenging optimization problem. Unfortunately, I will only be able to offer limited support in coding / debugging.

Katharina Galor, PhD

I agree to provide consultation to the team regarding the user interface and practical application of the 3D assembly software. I will also provide the team with experiential information regarding the assembly of real potsherds and how it might apply to virtual assembly. I'm willing to donate 30 minutes to an hour of my time per week for at least two weeks to this end.

Curricula Vitae:

Jason Mallios

SUMMARY
Web programmer, Brown University Master of Computer Science student.
Skills: ASP (Classic and .NET), Cold Fusion, PHP, DBMS (Access, SQL Server), Visual Basic, C, C++, Java, Perl, JavaScript, DHTML, CSS, SSL, Visual Studio, Photoshop, Illustrator, Pagemaker, Quark Xpress, Dreamweaver, Flash, Fireworks.
Environments: Windows / IIS, UNIX AIX / Apache, Mac, Linux.

WORK EXPERIENCE
Web Designer, The University of Texas System Administration-Employee Group Insurance (EGI) (2/00-6/03; reclassified from Graphic Designer 9/02)

* Designed and programmed group insurance Web site, www.utsystem.edu/egi, for 80,000 subscribers, and their dependents, at 15 campuses statewide. This W3C-accessible site receives between 6,000 and 30,000 unique visitors a month and is implemented with an underlying DBMS, server- and client-side scripts, and style-sheets.
* Worked with customers to design and build a secure Web-based publication-ordering and reporting system for campus HR offices and printing vendors. The system requires SSL logon, publication submission and ordering, and various public, private and user-specific reports.
* Laid out, edited, prepared for press, and arranged delivery of 4-color publications to campus HR offices and members.
* Successfully managed a $120,000 to $170,000 annual printing budget.

EDUCATION
Master of Science, Computer Science, Brown University (in progress)
Certificate of College Credit in Computer Science, St. Edward?s University (2000-02)
Bachelor of Arts in Liberal Arts specializing in English and philosophy, St. Edward's (1995-97)
Archaeology Study Abroad, Universidad de Querétaro, Querétaro, México (Summer 1995)

HONORS
John S. Trout Scholar - St. Edward's University School of Natural Sciences, $5,000 award (Fall 2001, Spring 2002)
Dean's List - St. Edward's
Alpha Chi National College Honor Scholarship Society - St. Edward's Chapter
Professional Scholarship - St. Edward?s, $1,000 award for student paper layout & design (Spring 1997)

RESEARCH
Algorithms and complexity theory, human-computer interface, Brown University (Fall 2003)
W3C accessibility study of www.utsystem.edu/egi (2002-2003)
Study of Python?s grammar, binding, typing and object-oriented implementation (Spring 2002)
Linear transformations in an Open GL rendering (Fall 2001)
Comparison of bandwidths from 4 different nodes of cable ISP in South Austin using analysis of variance (Fall 2001)
DBMS queries (Fall 2001)
Swing vs. AWT in Java (Summer 2001)

Cagatay Demiralp

Journal Papers:

- "In vivo measurement of contact areas and ligament lengths in the distal radioulnar joint" G. E. Marai, D. H. Laidlaw, C. Demiralp, S. Andrews, C. M. Grimm, and J. J. Crisco, IEEE Trans. On Biomedical Eng., in publication, 2003.
- "Visualizing Diffusion Tensor MR Images Using Streamtubes and Streamsurfaces" S. Zhang, C. Demiralp, and D. H. Laidlaw, IEEE TVCG, Vol. 9, No. 4, October-December 2003.

Conference Papers:

- "Subjective Usefulness of CAVE and Fish Tank VR Display Systems for a Scientific Visualization Application", C. Demiralp, D. H. Laidlaw, C. Jackson, D. Keefe, and S. Zhang, poster abstract, IEEE Visualization 2003, Seattle, October 2003.
- "Contact Areas and Ligament Lengths are Abnormal in Patients with Malunited Distal Radius Fracture Despite Normal Radioulnar Kinematics" G. E. Marai, D. H. Laidlaw, C. Demiralp, C. Grimm, J. J. Crisco, D. C. Moore, and E. Akelman, IV World Congress of Biomechanics, Calgary, August 2002.
- "Modeling and Visualization of Inter-Bone Distances in Joints" C. Demiralp, G. E. Marai, S. Andrews, D. H. Laidlaw, J. J. Crisco C. Grimm, IEEE Visualization 2001, San Diego, October 2001.
- "Visualizing Diffusion Tensor Volume Differences" M. J. da Silva, S. Zhang, C. Demiralp, and D. H. Laidlaw , IEEE Visualization 2001, San Diego, October 2001.
- "Visualizing the differences between diffusion tensor volume images" Marco DaSilva, Song Zhang, Cagatay Demiralp, and David H. Laidlaw. In Proceedings ISMRM Workshop in Diffusion MRI: Biophysical Issues, pages 237-238, March 2001.
- "An Immersive Virtual Environment for DT-MRI Volume Visualization Applications: A Case Study" S. Zhang, C. Demiralp, D.F.Keefe, M. J. da Silva, D. H. Laidlaw, B. D. Greenberg, P.J. Basser, E.A. Chiocca,C. Pierpaoli T.S. Deisboeck, IEEE Visualization 2001, San Diego, October 2001.
- "Toward Application of Virtual Reality to Visualization of DT-MRI Volumes" S. Zhang, C. Demiralp, D.F.Keefe, M. J. da Silva, D. H. Laidlaw, B. D. Greenberg, P.J. Basser, E.A. Chiocca,C. Pierpaoli, T.S. Deisboeck, MICCAI 2001.
- "Interactive Visualization of 3D Carpal Kinematics and Bony Anatomy" J. J. Crisco, C. Demiralp, D. H. Laidlaw, A-P. C. Weiss, E. Akelman, and S. W. Wolfe, Scientific Exhibition, ASSH 56th Annual Meeting, Baltimore, MD, October 2001 (awarded for "Best Scientific Content" and "Best Scientific Layout and Presentation")
- "Usability Evaluation of a Set of Cognitive Tool Software by Teacher Educators" E. Orhun, C. Demiralp, 2nd International Conference on Technology in Teaching and Learning in Higher Education, June 2001, Samos Island, Greece.

Vadim Slavin

EXPERIENCE:
September 2003 to Present
CONSULTANT, SOFTWARE DEVELOPER: "WhyData Works", 3 Richmond Sqr, Providence, RI
- Served as a software development and IT consultant to the developing business software solution.
- Helped develop, analyze, test and integrate a software suite using .NET 3-Tier architecture.

July 2002 to August 2003
ASSOCIATE, BUSINESS ANALYST: "American Management Systems Inc", 4050 Legato Rd, Fairfax, VA
- Performed research, analysis, and documentation of ERP solution project and software system.
- Created testing guidelines and supervised system testing for business requirements of the Human Resources Management software.
- Actively performed the duties of Subject Matter Expert for the ERP business solution.
- Conducted training sessions with the clients and served as the functional expert on the client site.

Summer of 2000, 2001
ANALYST, APPLICATIONS DEVELOPER: "Merrill Lynch", 101 Hudson St, Jersey City, NJ
- Participated in every stage of software development in a global financial firm: design, implementation, development, debugging and testing R all following company"s standards and procedures.
- Helped develop advanced features for software now used by ML Financial Analysts.
- Oversaw the production of a standalone software system using VB, VBScript, JavaScript, ASP, ActiveX, HTML, XML, SQL programming.
- Participated in seminars in telecommunications, presentation skills, and financial industry overview.
- Met with company"s top executives to gain knowledge and understanding of ML's global business strategy.

EDUCATION:
August 2003 to Present - Brown University, Providence, RI 02912
- Candidate for Master of Science in Computer Science.
    - Research Area of Interest: Scientific Visualization of higher dimensional, multivariate data.
    - Thesis Project: 3D Immersive Visualization of Topological Defects in Liquid Crystal Systems.

September 1998 to May 2002 - Brown University, Providence, RI 02912
- Bachelor of Science with Honors, Magna Cum Laude, National Honor Society (ÓÎ), 3.9 GPA.
- Honors Bachelor of Science in Math-Physics (3.85 GPA);
- Bachelor of Arts in Computer Science (4.0 GPA).
- Main courses taken: Honors and graduate level Math courses such as Differential Equations, Multidimensional and Differential Geometries, Combinatorial Topology, Complex Analysis. GPA 3.82

Stuart Andrews

Qualifications:

I am a Ph.D. candidate working with Professor Thomas Hofmann in the Machine Learning group at Brown University. My current work concerns the design of margin-based learning algorithms that maintain generalization ability when learning from ambiguous, or partially labeled training data. My goal is to apply these techniques to object detection and recognition problems, to enable efficient content-based indexing and retrieval of images.

Skills:

I am a proficient programmer of Matlab, C, C++, and HTML codes, with moderate Perl and Java programming experience. I have seven years experience with UNIX.

Education:

2002 - present	Ph.D., Computer Science	Brown University
1999 - 2002	M.Sc., Computer Science	Brown University
1997 - 1999	M.Sc., Computer Science	University of Toronto
1993 - 1997	B.Sc., Mathematics and Computer Science	University of Toronto

Research Projects:

2002 - 2003	Multiple Instance Learning	Brown University
1999 - 2002	Virtual Reconstruction of Pottery Vessels	Brown University
1997 - 1999	Feature Curves on 3D Surfaces	University of Toronto
1997 - 1998	3D Reconstruction of Brain Surface	The Rotman Institute, Toronto

Selected Publications

NIPS 2002 - Support Vector Machines for Multiple-Instance Learning, with I. Tsochantaridis and T. Hofmann.

AAAI 2002 - Multiple-Instance Learning with Generalized SVM, with I. Tsochantaridis and T. Hofmann.

AAAI 2002 - A Framework for Reconstructing Pottery Vessel, with D. H. Laidlaw.

ICPR 2002 - Bayesian Virtual Pot-Assembly from Fragments as Problems in Perceptual-Grouping and Geometric-Learning, with D. B. Cooper, et al.

IEEE Trans. on Biomedical Engineering 2002 - In vivo measurement of contact areas and ligament lengths in the distal radioulnar joint with G. Marai, D. H. Laidlaw, C. Demiralp, C. Grimm, and J. J. Crisco.

Awards

1999	Entrance Scholarship	Brown University
1997	Open Master's Fellowship	University of Toronto
1996	Regent's Academic Excellence Scholarship	Victoria College
1993	Canada Scholarship for Science and Engineering	University of Toronto

Katharina Galor

Positions:
1998 - present Visiting Assistant Professor, Center for Old World Art and Archaeology, Brown University
1996 - 2000 - Adjunct Professor, School for Overseas Students, Hebrew University of Jerusalem
1998 - 2000 - Adjunct Professor, École Biblique et Archéologique Française de Jérusalem
1997 - 1998 - Visiting Assistant Professor, Classics Department, Tufts University
Post-Doctoral Fellow, Institute of Archaeology, Hebrew University of Jerusalem
1989 - 1991 - Lecturer, University of Aix-Marseille, France.

Degrees:
1996 - Ph.D. in Archaeology, Brown University
D.E.A. (Diplôme d'études approfondi) in Art History and Archaeology, (magna cum laude), University of Aix-Marseille, France
MAITRISE in Art History and Archaeology (magna cum laude), University of Aix-Marseille
1988 - LICENCE in Art History and Archaeology, University of Aix-Marseille
1987 - D.E.U.G. in Art History and Archaeology, University of Aix-Marseille

Thesis and Dissertation Topics:
1996 - Ph.D., Center for Old World Art and Archaeology, Brown University:
"Domestic Architecture in the Galilee and the Golan During the Roman and Byzantine Periods"
D.E.A. in History and Archaeology, University of Aix-Marseille:
"The Culture of the Jews in Ancient Rome"
Maîtrise in Art History and Archaeology, University of Aix-Marseille:
"The Mosaic Floors in Palestine During the Rule of Herod the Great"

Areas of Specialization:
Roman and Byzantine Palestine: sacral, civic and domestic architecture, mosaics and wall decoration, town planning and water installations

Courses Taught and Able to Teach:
The Archaeology of Jerusalem
The Archaeology of Palestine
Ancient Synagogues, Churches and Mosques in Palestine
The Archaeology of Qumran and the Dead Sea Scrolls
The Cities of the Decapolis
Monumental and Domestic Architecture in the Roman and Byzantine Periods
The Art and Archaeology of Syria-Palestine
The Art and Archaeology of Babylonia
The Art and Archaeology of Mesopotamia
The Art and Archaeology of Phoenicia

Excavations:

1985	Emek Rephaim, Jerusalem, Israel
1985-1987	Roquevert, France
1988-1990	Staff, Old Jewish quarter of Cavaillon, France
1991	Staff, Vigna Barberini, Rome, Italy
2000	Staff, Sepphoris, Israel
2001	Co-Director, Qumran, Israel
2002	Director of Archaeological Field School, Ein Gedi, Israel

Proposal

An Exploratory Visualization for Reverse Engineering

Submitted by : Guillaume Marceau
With the collaboration of : Eileen E. Vote, David Eigen and Steve Reiss

Abstract

In practice, reading and understanding somebody else's code a difficult task, since most often the program's documentation is inadequate. We propose to extend the previous work on software visualization for reverse engineering with two novel insights. First, a program visualization should reuse as much of the abstraction mechanism used in the program as possible. In that end, we want to create renderings of the public/private structure of OO programs, and of typical coding idioms, starting with the formal design patterns. Second, current program visualizations struggle with representing the large number of aspects coming from their backing program analysis – confidence values, in particular. We propose to take advantage of new developments in art-inspired visualizations to handle this multiplicity of aspects.

Problem description

When working on his own code, a programmer maintains a mental model of the design and of the layout of the code. Code is like a book with an overwhelming number of forward references: without such mental summary, reading code ranges from tedious to useless.

In order to cope with this effect, programmers spend plenty of their time writing documentation, or rather, they should, but don't. In order to cope with documentation which is outdated, incomplete, misleading, missing or simply non-existent, programmers end up spending even more time reverse-engineering code from the source. Moreover, there is a vacuum of tools that assist in the construction of a mental model from code.

Proposal overview

We propose to build an exploratory program visualization tool for reverse engineering that uses design sketches as its driving metaphor.

We claim source code is not the best representation for such archaeological work as reverse engineering. To supplement their prose documentation, programmers commonly use hand-made sketches, notably node-and-edge graphs (fig. 1) and pile-of-box diagrams (fig. 2). Our tool will assist in the reconstruction of design sketches by salvaging design artifacts from the source code. It will present these artifacts on an interactive window where the user can move them and recombine them until the design stands out.

Also, we claim that a program visualization tool should reuse as much of the towering structure of programming languages as possible. Programming constructs – functions, objects, modules and so forth – form a tower of abstraction: each level hides details from the previous levels. Furthermore, programmers have a long tradition of using these mechanism to control complexity. As such, programs come pre-clustered into logical black-boxes. These black-boxes, as their name implies, gives a radically different view when seen from the outside-in versus from the inside-out. Our tool will let the user explore this variety of viewpoints interactively.

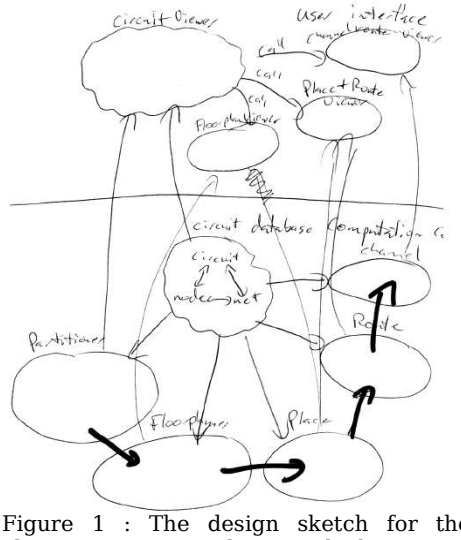


Figure 1 : The design sketch for the electronic circuit editor “Aphyd”. Among other things, it illustrate the model/view pattern (long horizontal line), the chain of responsibility pattern (bold arrows at the bottom), and the composite pattern (the node at the center).

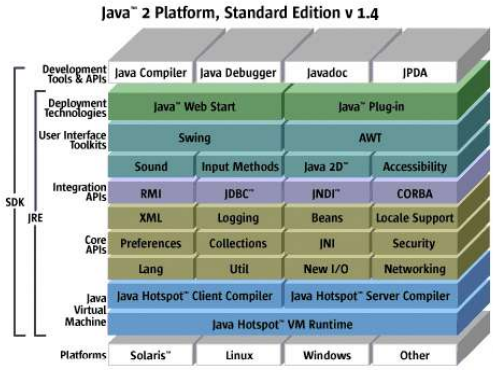


Figure 2 : A pile-of-box representation of the design of the Java platform.

To tackle the previous two aspects, we will bring together some recent work in program analysis, the latest in towering program visualization, and the latest in art-inspired visualization.

Visualization of formal design patterns

The tower of abstraction mechanisms does not end with language-defined constructs. Programmers create further levels of clustering using coding idioms. For example, getter/setter methods come in pairs, and functions are sometimes divided into logical sections with comments.

As a first step at extending the tower of abstraction, we will place particular attention on the visualization of the formal design patterns [3]. For example, a facade pattern is a class which republishes the functionality of a few other classes in a unified interface. A graphical representation of the pattern should capture, without clutter: which classes are being abstracted, which methods implement the abstraction, and which classes uses the abstraction.

First, formal patterns are interesting for reverse engineering because they

capture an intermediate level of abstraction between the class and the module. Second, because they have so many multiple aspects, design patterns present a singular visualization challenge. Finally, formal design patterns appear in our initial sampling of sketches, suggesting that they are an effective communication tool. Yet, we are not aware of any attempt to visualize them in code.

For this part of the proposal, we will implement a family of program analyzes by Heuzeroth [4] which automatically detect formal patterns, without relying on naming conventions. First they inspect the text of the code and select a collection of candidate sites. Then, the algorithms instrument the candidates to capture their run-time behavior. Finally, the captured data is used to filter the list of candidates down to a few targets. Their methods report a two-bit confidence value for each decision. Our project will attempt to visualize the output, including the error terms on each detection.

Towering program visualization

The Rigi [5] project at the University of Victoria is a program visualization system which preserves the tower of abstraction. It allows to fold undesired details by selectively closing and opening black-box icons representing functions, classes and modules. It also offer an automatic graph layout engine and a step-wise zoom setting for each level of the abstraction tower. Their approach is a step in the right direction, and we intent to extends their work.

The shortcoming of Rigi we wish to address is, although hiding details can make the general pattern easier to see, it requires a demanding amount of micro-managing (fig. 3).

Let's recall the black-box viewpoints we mentioned earlier. From inside a class, you can sees its member, either private or public, and also its super-class' protected members. From the outside of the class, you only see the public members, and from the outside of the module, you only see the exported names.

We want to implement navigating the visualization according to viewpoints and integrate them with our visualization of formal design patterns.

Art-inspired visualization

Our interest in an interactive approach follows from a case study at the University of Waterloo [2]. They used the Linux kernel as a test target for the usual collection of program visualizations. They discovered that simple pattern detection analyzes could not distinguish between intensional and accidental design artifacts. Design bugs and performance tweaks were reported at the same level of importance as important design relationships. Take for example one module A which shares data with module B, which in turn shares it with module C. If only once, maybe for performance reasons, A communicates directly with C, adding the edge (A-C) does little to clarify the visualization. This result suggests that fully automatic reverse engineering is either difficult or impossible.

We hope that an art-based visualization can bring some light to this problem. First, art approaches have shown some success at representing multi-faceted values, such that we believe they are applicable to the visualization of formal design patterns [7]. Second, we think an interactive sketch pad, backed by automatic analyzes, could present a useful editing surface. On it, a programmer could record his growing understanding of the design, in real time, as he discovers it, and leave a useful piece of documentation behind him. We think that an art-based approach can help representing absconding doubts of the programmer about his own reverse engineering conclusions, as the editing progresses. Finally, our initial survey of programmer node-and-edge design sketches reported various interesting usages of textures and shapes which were used to punctuate the parts of the graph according to their function.

Support facilities

Steve Reiss here at Brown runs the Clime software engineering database. This database contains an extensive collection of program analyzes for simple design artifacts. It computes, stores and indexes the use-def pairs for variables, function references and class inheritance relationship, among others. The Clime database is already populated with the data from several software systems. It will provide the ground work necessary for a quick implementation of the design detection paper. The Clime database is also a readily available collection of test target programs for our tool.

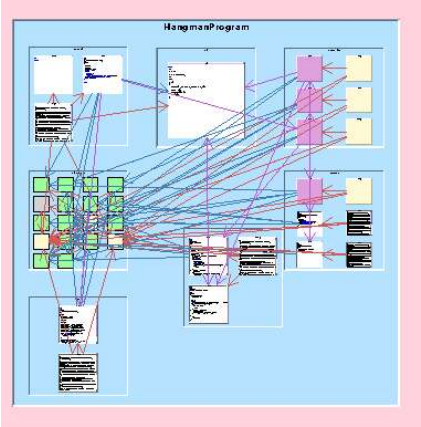


Figure 3 : The SHriMP program visualization. Selectively collapsing unnecessary details help controlling the clutter.

The PI is well versed in the methods of program analysis. He has participated in the creation of the Soot program analysis and decompiling framework for Java [6], built at the McGill university.

Timeline

- Week 1, User survey of design sketches
- Week 2, Implementation of the pattern detections
- Week 3, Implementation of the pattern visualization
- Week 4 & 5, Creation of the interactive scratch pad
- Week 6, Preliminary user evaluation of the tool

References

[1] J. Aldrich, C. Chambers, and D.Notkin. Archjava: Connection software architecture to implementation, 2001.

[2] Ivan T. Bowman, Richard C. Holt and Neil V. Brewster. Linux as a Case Study: Its Extracted Software Architecture, 1999

[3] Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides. Design Patterns, Elements of Reusable Object-Oriented Software, 1995

[4] Dirk Heuzeroth, Thomas Holl, Gustaz Hogtrom and Welf Lowe.

Automatic Design Pattern Detection, 2003

[5] Margaret-Anne D. Storey, Kenny Wong and Haussi A and Muller. Rigi: A Visualization Environment for Reverse Engineering, 1997

[6] Raja Vallée-Rai, Laurie Hendren, Vijay Sundaresan, Patrick Lam, Etienne Gagnon and Phong Co. Soot – a Java optimization framework, 1999

[7] Eileen E. Vote, Denial Acevedo, Cullen Jackson, Jason Sobel, and David H. Laidlaw. Design-by-example: A scheme for designing using examples from art, 2003

Support letters

I enthusiastically endorse your proposal for "An Exploratory Program Visualization for Reverse Engineering," and look forward to collaborating with you on the creation of a new framework for visualizing software patterns. A sophisticated graphical representation can facilitate analysis-by-exploration at a variety of levels and has the potential to shorten what is currently a long and tedious process. In addition, the framework and the supplemental tools created could extend to other application areas in information processing and for visualizing complex multitiered systems. I will contribute my expertise using art-based techniques of representation and from designing visualizations of complex multi-valued datasets to this effort and look forward to the exciting process of innovation.

Sincerely,

Eileen L. Vote, Ph.D.

Eileen L. Vote
Brown University
Box 1910, Department of Computer Science
Providence, Rhode Island 02912
401.863.7651
email: *evote@cs.brown.edu*
http://www.cs.brown.edu/~evote

Experience

Postdoctoral Research Fellow - **Visualization Research Lab - Department of Computer Science - Brown University**, 2001 to present.
Visualization Research Projects: Develop techniques to visualize complex multivariate datasets with vector, tensor and scalar values in two dimensions by example using art-based principles of composition (color, texture, layering). Building a new system, EVOLVIS, to provide a series of automatically generated visualization solutions using a genetic algorithm. The approach utilizes strengths in the human visual system such as pre-attentive cues to help users interpret complex datasets.

Research Assistant – **Engineering - Brown University,** 1999 to 2001.
First graduate of joint Archaeology and Computer Science Interdisciplinary Ph.D.
"A New Methodology for Archaeological Analysis: Using Visualization and Interaction to Explore Spatial Links in Excavation Data"

Ph.D. Research: Developed new methods for archaeologists to visualize, survey and analyze three-dimensional aspects of the archaeological record.

Implementation and Testing: The prototype – ARCHAVE - utilizes a novel visualization paradigm for access inside a three-dimensional (immersive virtual-reality) Cave environment and new interaction techniques for archaeologists to perform crucial analysis tasks. User tests show that this method is more effective and provides tangible results for archaeologists.

Co-Author and Collaborator - **NSF-KDI Research Grant - Brown University,** 1998 to 2003.
Key role in the planning, writing and submission of a successful proposal for an NSF-KDI grant to develop tools for modeling, visualization and analysis of the archaeological record. *NSF BCS-9980091, award, $1,370,870, September 1999 – January 2003.*

Researcher - **Brown University Sponsored Excavations – Petra, Jordan,** 1998.
Surveying: Planning and execution of photogrammetric survey to record and generate three-dimensional models of architecturally-significant areas of the Great Temple site in Petra, Jordan.

Teaching Assistant - **Department of Architectural History - Brown University,** 1994 to 1996.

Consultant - **Department of Architectural History - Brown University,** 1994 to 1996.

Architect - **Consulting for Architects - Boston, MA,** 1991 to 1993.

Architect - **Robert Luchetti Associates - Cambridge, MA,** 1990 to 1991.
Intern - **Payette Associates - Boston, MA, 1989 and Cambridge Seven Associates - Cambridge, MA** 1986.

Education

Ph.D., Archaeology and Computer Science, Brown University, 2001.
M.A., Architectural History, Brown University, 1997.
B.A., Art and Architecture (Double Major)**, Rice University,** 1990.

Invited Talks

Columbia University, Department of Computer Science, April 2002.

The Inauguration of Ruth Simmons, Brown University's new President, Selected presentation of research, November 2001.

Italy- United States Remote Sensing Workshop, Boston University, November 2001.

American Schools of Oriental Research Annual Meeting, Applied Technologies Speaker, Nashville, TN, October 2000.

Media

Higher Learning Magazine, 2003
Higher Learning Magazine. The Shape Lab. *Higher Learning Magazine*, May/June 2003.

MSNBC Television Documentary, 2001 – The Archave System is featured in the new documentary, "Hi- Tech Archaeology," (in production).

Publications

”Design- by- example: A schema for designing visualizations using examples from art.” Eileen Vote, Daniel Acevedo, Cullen Jackson, Jason Sobel, and David H. Laidlaw. In *SIGGRAPH 2003 Sketches and Applications*. IEEE, 2003.

"**Discovery Petra: Archaeological Analysis in Virtual Reality,**" Eileen Vote, Daniel Acevedo, David H. Laidlaw and Martha S. Joukowsky, IEEE Computer Graphics and Applications, Special Issue on Art History and Archaeology, September 2002.

“Bayesian virtual pot- assembly from fragments as problems in perceptual- grouping and geometric- learning.” David B. Cooper, Andrew Willis, Stuart Andrews, Jill Baker, Yan Cao, Dongjin Han, Kongbin Kang, Weixin Kong, Frederic Leymarie, Xavier Orriols, Senem Velipasalar, Eileen Vote, Martha Joukowsky, Benjamin B. Kimia, David H. Laidlaw, and David Mumford. In *Proceedings of ICPR*, volume 3, pages 30297- 30302, 2002.

"**Archaeological Data Visualization in VR: Analysis of Lamp Finds at the Great Temple of Petra, a Case Study,**" Daniel Acevedo, Eileen Vote, David H. Laidlaw and Martha S. Joukowsky, In proceedings of IEEE Visualization 2001, San Diego, California, October 2001, *Award for Best Case Study at IEEE Visualization 2001.*

“Assembling Virtual Pots from 3D Measurements of their Fragments,'' David B. Cooper, Andrew Willis, Stuart Andrews, Jill Baker, Yan Cao, Dongjin Han, Kongbin Kang, Weixin Kong, Frederic F. Leymarie, Xavier Orriols, Eileen L. Vote, Martha S. Joukowsky, Benjamin B. Kimia, David H. Laidlaw, David Mumford, Senem Velipasalar, Proc. VAST 2001.

"**A New Methodology for Archaeological Analysis: Using Visualization and Interaction to Explore Spatial Links in Excavation Data,**" Eileen Vote, Ph.D. Thesis, Brown University, Providence, RI, 2001.

"**Archave,**" Daniel Acevedo and Eileen Vote, Sidebar in article "**Immersive VR for Scientific Visualization: A Progress Report**" by Andries van Dam, Andrew S. Forsberg, David H. Laidlaw, Joseph J. LaViola Jr. and Rosemary M. Simpson, IEEE Computer Graphics and Applications, Vol. 20, No. 6, November/December 2000.

"**Virtual Reality and Scientific Visualization in Archaeological Research,**" Eileen Vote, Daniel Acevedo, Martha S. Joukowsky and David Laidlaw. in Virtual Archaeology, Proceedings of the VAST2000 Euroconference held in Arezzo, November 2000, Oxford, Archaeopress, 2002.

"**ARCHAVE: A Virtual Environment for Archaeological Research,**" Daniel Acevedo, Eileen Vote, David H. Laidlaw and Martha S. Joukowsky, Work in Progress report presented at IEEE Visualization 2000, Salt Lake City, Utah, October 2000.

"**ARCHAVE - A Three Dimensional GIS for a CAVE Environment,**" Eileen Vote, Daniel Acevedo, Martha S. Joukowsky and David H. Laidlaw, Proceedings of Computer Applications in Archaeology, 28th annual international conference. Held in Ljubljana, Slovenia, April 18- 21, 2000. Archaeopress, 2000.

"**The SHAPE Lab - and the development of a shape language for 3D artifacts,**" Frederic Leymarie, David Cooper, Martha S. Joukowsky, Ben Kimia, David H. Laidlaw, David Mumford and Eileen Vote, Proceedings of Computer Applications in Archaeology, 28th annual international conference. Held in Ljubljana, Slovenia, April 18- 21, 2000. Archaeopress, 2000.

"**Using Desktop Photogrammetry to Document Archaeological Remains: The Great Temple at Petra, Jordan,**" Eileen Vote, and Martha S. Joukowsky, Proceedings of Computer Applications in Archaeology, 27th annual international conference. Held in Dublin Castle April, 1999 Dublin, Ireland. Oxford, Archaeopress, 2000.

Curriculum Vitae - Guillaume Marceau

965 Grant, Longueuil, Québec, J4H 3J8
450-670-3617, gmarceau@cim.mcgill.ca

/** Profile ***/

Computer science graduate with demonstrated ability to deliver. Experience includes: three Pan-American competitions, contributions to two different academic research teams, and several programming contracts. Proficient C++, Java, Ocaml and Scheme programmer. Excellent academic background with strong focus on research. Specialized in Ai/Robotics and Compiler/Programming language design.

/** Selected Accomplishments ***/

. Head coder for McGill at Sony's International Robocup Competition.

. Built three compilers: one web language, one circuit design language and one concurrent control language.

. Authored Micropouce, the geomatic carpooling matcher in use by Bell Canada, Trizec Hann and the Charles-Lemoyne Hospital.

/** Education ***/

B.Sc. Computer Science, CGPA 3.4/4.0 - June 2001
McGill University, Montreal
DEC Pure Sciences - May 1997
Cegep Edouard-Montpetit, Longueuil
Languages : Native French, fluent English, beginner German

/** Relevant Books Read ***/

. The Mythical Man-Month, by Frederick P. Brooks
. Code Complete, by Steve C. McConnell
. The Deadline, by Tom Demarco

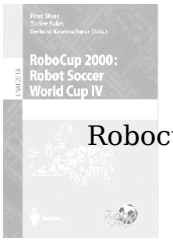
/** Awards and Fellowships ***/

Natural Sciences and Engineering Research - 1998 and 1999
Council of Canada (NSERC) Undergraduate Award (2x5000$)

First place, Programming Contest of McGill's ACM Chapter - Oct 1998

First place, AAAI's Find Life on Mars Challenge, Madison, USA - Aug 1998

/** Publications ***/



Etienne M. Gagnon, Laurie J. Hendren and Guillaume Marceau. Efficient Inference of Static Types for Java Bytecode, published at SAS2000. (21 pages)
http://www.sable.mcgill.ca/publications/#sas2000

Robocupers 2000, Peter Stone, Tucker Balch. Robocup 2000 : Robot Soccer World Cup IV (Lecture Notes in Computer Science, 2019.). (pages 627-630)
http://www.amazon.com/exec/obidos/ASIN/3540421858/qid%3D997632263/002-9227105-1196020

/** Academic Projects ***/

Project Leader for McGill's RedDogs - Summer 1999 and 2000
Melbourne, Australia

Competed against world-class research teams at RoboCup, Sony's Robotic Soccer World Cup, and placed 6th. Handled the dynamics of a team of 6. Implemented the Monte Carlo Localization Algorithm. Invented an interpreted custom-purpose concurrent control language for our Ai. Designed a stable, lightweight vision system based on iterated unification.

The system of 40000 lines runs on embedded four-legged robots. It includes modules for compressed

logging, remote debugging and offline simulations.
http://www.cim.mcgill.ca/~gmarceau/papers/reddogs-robocup2000.ps (11 pages)

Keytechs : C++, OO/OOD/OOP, CaML, XP, Project management, Embedded systems, Language design, Computer vision, Real-time signal processing, Ai, CVS, Make, Emacs

Inference of class parameterization - Apr 2000
Sable Compiler Research Group

Designed and implemented a heuristic algorithm for the inference of implicit class parameterization on Java bytecode. This was an important step towards both useful decompilation of bytecode and the structured removal of redundant dynamic casts in Java. This work is now included in the Soot Java Optimization Framework.

http://www.cim.mcgill.ca/~gmarceau/papers/parameter-inference.ps (14 pages)

Keytechs : Java, OO/OOD/OOP, JVM, Bytecode, Optimizing compilers design, Data flow analyses

Object Recognition System for the AAAI's - Summer 1998
Find Life on Mars Challenge, Madison, USA

Designed and implemented an object recognition system and won the North-American-level competition with 95% accuracy on 7 classes of geometric volumes.

Keytechs : C++, OO/OOD/OOP, Computer vision, Signal processing

/** Related Experience ***/

Private Tutor - May 2000 to April 2001

Taught university level intro to programming. Prepared lessons for students with difficulties.

Keytechs : C, Java, Teaching, Moral support!

Teaching Assistant for the compiler design class - Jan to May 2000

Prepared assignments and marked projects. Gave tutorials, advised on compiler and language design.

Keytechs : Flex, Bison, Teaching, Presenting

Independent software development and sales - since 1996
Micropouce senc.

Developed, marketed, and sold professional-quality geomatic software. Lobbied to the related governmental departments. Experience in long term support of complex software.

Keytechs : C++, SQL, VC++, MFC, Visual Basic, Signal processing, Data compression, User interface design

Database development and multimedia interfaces - through 1997
Injava inc. Montreal

Programmed and shipped mass-distribution customer-grade software.

Keytechs : C++, SQL, VC++, MFC, Visual Basic, Multimedia under Windows, User interface design

Novel Methods for the Visualization of Polychromatic Flow Cytometry Data

Abstract

Rapid increases in the ability of flow cytometry to measure many fluorochromatic markers give rise to high dimensional datasets that are difficult to analyze with traditional approaches. We propose novel methods of representation and interaction utilizing 3D graphical visualization to overcome some of these challenges.

Collaborators

Brown University, Computer Science Graphics Group
Dmitri Lemmerman
Guillaume Marceau
Daniel Grollman

Harvard Medical School, Joslin Diabetes Center Immunology Group
Christophe Benoist, M.D., Ph.D.
Richard Park

Novel Methods for Visualizing Polychromatic Flow Cytometry Data

Introduction

Polychromatic flow cytometry is an essential tool in many sciences that study the biology of the cell. (Shapiro 1995) Flow cytometry is a technique for measuring antigen expression in cells. Biologically inert flurochromes are conjugated with antibodies and introduced into a population of cells. The cells are then passed single-file in front of a laser, and the reflected light intensity from the flurochromic markers is recorded. Though the technology required to measure fluorescence for up to 11 distinct surface marker flurochromes per cell has been developed (Baumgarth and Roederer 2000), the visualization methods employed in the analysis of such data have not significantly progressed beyond their state for the one- or two-color cases. Subsequently, it can be difficult or impossible to accurately identify subpopulations of cells that are differentiated by three or more dimensions of fluorescence values.

Nevertheless, visualization techniques for creating meaningful representations of generalized multidimensional data have been studied extensively, both on a theoretical level (Bertin 1967, Tufte 1990) and in the implementation of actual visualization systems (MacKinlay 1986). Seemingly for a simple lack of dialog between the visualization and cytometry communities, these techniques have not yet been introduced into the standard workflow of flow cytometry data analysts.

Goals

The goal of this project is to apply modern techniques for the visualization of multidimensional data to a driving problem in flow cytometry data analysis. Additionally, we expect that the subtleties of the data in this domain will necessitate the conception of novel methods for multidimensional representation.

Specifically, our collaboration will focus on the polychromatic flow cytometry data generated for the study of cellular and molecular pathways governing diabetes onset in NOD (Non-Obese Diabetic) mice, a transgenic breed that has been shown to develop autoimmune diabetes several weeks after birth. (Leiter 1997) Using flow cytometry, the amount of various cell surface markers of the pancreatic islet and immune cells of the mice are measured at different intervals after birth. From these measurements, one can evaluate the status of the immune system and note the changes in cell populations that accompany the autoimmune process. Using these clues aspects of the disease process can be inferred. This project will be successful if our new visualization methods allow for more accurate and more comprehensive inferences in this regard.

Significance

The ability of immunology researchers to make correct inferences concerning the cellular and molecular pathways and timelines in NOD mouse diabetes onset is significant given that the autoimmune response system of such mice is known to have similar characteristics to that in humans. The discovery of a particular step of these pathways (e.g. the expression of a specific antigen at a particular moment in development) will allow for very specific targeting of that step through drug therapy. In the long term such therapy could be applied to humans as an effective treatment for autoimmune diabetes, a disease currently treatable only through a lifetime of regular insulin injections.

Related Work

There has yet to be a paper published in the major visualization literature that addresses the problem of polychromatic flow cytometry visualization. The issue has been dealt with somewhat in the cytometry literature (Shapiro 1995), but never with the rigor necessary to make any technique above and beyond the 2D scatterplot practically effective.

The abstract problem of visualizing multidimensional data has, on the other hand, much treatment in the literature. Starting with the seminal work in Bertin and continuing with the subsequent work of such researchers Tufte, Cleveland, and Ware, the methods of representing information, especially in two-dimensional forms of signification, have been thoroughly explained. Moreover, systems to create effective visualizations, such as in MacKinlay's APT, have been implemented.

Research Plan

Our research will build on the theoretical framework of the above approaches to visualization in order to develop effective tools for representing and interacting with polychromatic flow cytometry data. The project will be executed in several passes to afford continuous dialog between the implementers (visualization team) and the users (immunology team).

First Pass

During the first step we will implement a three-dimensional scatterplot representation of flow cytometry data. We will provide basic navigational tools in a Fishtank VR interface such that the flow cytometry data analysts can readily explore these representations. It has been demonstrated that 3D visualization is superior for identifying substructures in node-link diagrams (Irani and Ware 2000). Our approach is novel in that it will test a similar hypothesis for a different class of diagram: the 3D scatterplot. It is our belief that this seemingly small step alone will spawn much interest on their part and provide better insight into the possibilities of higher-dimensional representations.

Second Pass

The next step will be to provide the data analysts with a 3D user interface that will allow analogous capabilities to the 2D tools currently used. Specifically, novel UI techniques will be needed to afford effective gating strategies that are necessary to explore the extents of distinct cell subpopulations. A possible starting point of this research could be an implementation similar to the SKETCH system (Zeleznik 1996), which provides intuitive controls for defining geometric primitives in 3D space. Our approach will necessarily require novelty above and beyond SKETCH as it is crucial that the data not be obscured by the interface employed for gating.

Third Pass

Once the basic tools are in place for representing and manipulating flow cytometry data in 3D, we will implement representations of higher dimensional subsets of the data. This work will build off of the visualization literature previously described. Novel methods for such representations will be needed as the current literature does not address the signification process of visualization nor the structure of the sign system in 3D.

Work Plan

Week 1: Implement 3D scatter plot. Deliver to Joslin.

Week 2: Get user feedback. Begin implementation of 3D user interface.

Week 3: Finish and deliver 3D UI. Adjust representation based on feedback.

Week 4: Experiment with methods of higher dimensional representation, delivering as appropriate. Gather comprehensive user feedback on 3D scatterplot and UI.

Week 5: Continue experimentation with higher dimensional representation. Begin work on final demo. Also, continue to gather user feedback.

Week 6: Finish final demo and prepare presentation.

Collaborators

The work will be done by three graduate students at Brown studying visualization, one Professor at Harvard Medical School, and one research assistant in his lab. The RA has experience working in Brown's Graphics Group, which will help bridge the communication gap between the disciplines involved.

Citations

Baumgarth, N. and Roederer, M. "A Practical Approach to Multicolor Flow Cytometry for Immunophenotyping." *Journal of Immunological Methods,* 243, 2000: pp. 77-97.

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Cleveland, W.S. and McGill, R. "Graphical perception: Theory, experimentation, and application to the development of graphical methods." *Journal of the American Statistical Association*, 79(387):531-554, September 1984.

Greimers, R., Rongy, A.M., Schaaf-Lafontaine, N., and Boniver, J. "CUBIC: A Three-Dimensional Colored Projection of Consort 30 Generated Trivariate Flow Cytometric Data." *Cytometry*, 12, 1991: pp. 570-5.

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Leiter E.H. 1997. "The NOD Mouse A Model for Insulin-Dependent Diabetes Mellitus." *Current Protocols in Immunology*, 15.9.1-15.9.23

Mackinlay, J. "Automating the design of graphical presentations of relational information." *ACM Transactions on Graphics*, 5(2):110-141, April 1986.

Shapiro, H.M. *Practical Flow Cytometry*. Wiley-Liss, New York: 1995.

Tufte, E. R. *Envisioning Information*. Graphics Press, Cheshire, Connecticut: 1990.

Zeleznik, R.C., Herndon, K.P., and Hughes, J.F. “SKETCH: An Interface for Sketching 3D Scenes.” *ACM Transactions on Graphics, Proceedings of SIGGRAPH ’96*, Addison Wesley, New York: 163-170.

CURRICULUM VITAE

Dmitri Lemmerman, dlemmerm@cs.brown.edu

Experience

Creation of applications from design phase to implementation to post-project analysis.

Programming experience in C/C++, Java, Perl, VisualBasic, VBScript, and JavaScript.

Graphics programming experience with OpenGL, World Toolkit, Java3D, Qt, and Swing.

Scientific visualization and virtual environment implementation using the CAVE environment.

Web application implementation using SilverStream, Java Servlets, ASP, CGI, HTML, XML, and XSL.

Database experience with SQL Server, Sybase, Oracle, and ADO.

Technical experience with Windows NT, Unix (Linux and Solaris), and MacOS environments.

Employment

Research Assistant
Brown University, Department of Computer Science, Graphics Group
Senior Researcher - Andrew Forsberg - (401) 863-7653
115 Waterman Street, Providence, RI 02912
June 2002 - Present

Planned, executed, and evaluated techniques for visualizing scientific data in immersive viewing environments. Developed advanced rendering and user-interface methods for addressing a wide range of scientific inquiries. Also, implemented a system to synchronize event-based applications in a tiled-display, cluster-rendering virtual reality setup.

Information Technology Intern
Goldman Sachs, Inc. (http://www.gs.com)
VP Core Tax and Legal IT - Karl Carlstrom - (212) 902-3618
10 Hanover Square, New York, NY 10005
May 2001 - August 2001

Designed and implemented web application to organize IT end user needs and map these needs to solutions for the next budgeting year. Responsibilities included visual database structure and application flow design, implementation with SQL stored procedures and SilverStream web application server, and continual adaptation to a broadening set of application requirements.

Education

Brown University
September 1998 - Present
B.A. Computer Science, 2002
Class of '04 M.Sc. in Computer Science

Teaching

Head Teaching Assistant - CS196-2: Virtual Reality: Immersion, Decisions, Empathy - Spring 2002

Awards

National Merit Scholarship Finalist – 1997

Volunteer

Pre-College Enrichment Program
Spring 1999 - Spring 2002

PCEP, sponsored by Brown University, mentors Providence high school students of promise, encouraging them to garner the skills and experiences necessary to succeed in the college admissions process, the college experience, and eventually the world at large. Responsibilities include weekly lesson planning and Saturday morning tutoring, lessons, and community service.

Daniel H. Grollman
grollman@aya.yale.edu

Education

2003-Present **Brown University**
PhD student in Computer Science

1999-2003 **Yale University**
Bachelor of Science: Electrical Engineering and Computer Science

1996-1999 **The Bronx High School of Science**

Previous Employment

June - Aug ’03 **Microsoft,** Software Design Engineer.
Supervisor: Gerry Cermak
- Design and implement P2P protocols for SPOT (Smart Personal Object Technologies)

Sep '01–May ’03 **Yale University Department of Computer Science**, Robotics Researcher.
Supervisor: Dr. Brian Scassellati
- Design, build, program, test and work with humanoid robots to test theories of social learning.
- Administer the lab’s website and computers.

June - Aug ’02 **Microsoft Hardware,** Intern Firmware Engineer.
Supervisor: Mark Hanson
- Wrote firmware for use in wireless products. Dealt with issues of RF interference, USB/PS2 communications, and usability.

May - Aug '01 **University of Edinburgh Division of Informatics,** Researcher.
Supervisor: Dr. Gillian Hayes
- Wrote code to interface several existing projects into a mobile robotic system that could recognize and react to human arm gestures, using no special equipment.
- Designed an coded a robotic companion, which followed along next to a person

Jan - May '01 **Yale University Department of Computer Science**, Teaching Assistant.
Supervisor: Dr. Paul Hudak
- Wrote and maintained code for use in the autonomous systems course.
- Designed and constructed a physical playpen for the robots in the course to maneuver in.

May '00 - Jan '01 **Yale University Department of Computer Science**, Research and Design
Supervisors: Drs. Paul Hudak, John Peterson, and Drew McDermott
- Expanded, developed and debugged Haskell FRP (Functional Reactive Programming) and Frob for use in robotic and coordinated motion research.
- Was part of the team that represented Yale at the Robocup 2000 competition in Melbourne, Australia. Developed and coded algorithms to control the robots during the competition.

Awards

1999 Intel Science Talent Search Finalist. (Formerly the Westinghouse)
Honor Student at the American Academy of Achievement’s Banquet of the Golden Plate
Finalist in the Lucent Global Science Scholars Contest
National Merit Finalist

BIOGRAPHICAL SKETCH

NAME	POSITION TITLE
Christophe Benoist	Senior Investigator and Section Head/Professor

EDUCATION /TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR(S)	FIELD OF STUDY
U. of Paris VII, Paris, France	M.D.	1980	Medicine
U. Louis Pasteur, Strasbourg, France	Ph.D.	1981	Molecular Biology

A. POSITIONS AND HONORS

1977 – 1981	**Graduate Student**, Laboratoire de Génétique Moléculaire des Eucaryotes, Strasbourg (France).
1981 – 1982	**Postdoctoral Fellow**, Fellow Leukemia Society of America, Dept. of Genetics, Stanford University Medical School, Stanford, California (USA)
1982 – 1983	**Postdoctoral Fellow**, Fellow Leukemia Society of America, Dept. of Medical Microbiology, Stanford University Medical School, Stanford, California (USA)
1983 – 1999	**Senior Investigator**, Department of Immunology, Institut de Génétique et de Biologie Moléculaire et Cellulaire, (previous Laboratoire de Génétique Moléculaire des Eucaryotes), Illkirch, C.U. de Strasbourg, (France)
1997 – 1998	**Sabbatical Visiting Professor**, Walter and Elisa Hall Institute, Melbourne (Australia)
1999 –	**Head, Section on Immunology and Immunogenetics/Senior investigator /Professor of Medicine**, Joslin Diabetes Center/Harvard Medical School, Boston, MA (USA).

B. SELECTED PEER-REVIEWED PUBLICATIONS (IN CHRONOLOGICAL ORDER)

C. Benoist, D. Mathis, M. Kanter, V. Williams and H. McDevitt: Regions of allelic hypervariability in the murine Aα immune response gene. Cell (1983) 34, 169-177.

D. Mathis, C. Benoist, V. Williams, M. Kanter and H. McDevitt: The murine Eαimmune response gene. Cell (1983) 32, 745-754.

M. Le Meur, P. Gerlinger, C. Benoist and D. Mathis: Correcting an immune-response deficiency by creating Eα gene transgenic mice. Nature (1985) 316, 38-42.

D. Landais, C. Waltzinger, B.N. Beck, A. Staub, D.J. McKean, C. Benoist and D. Mathis: Functional sites on Ia molecules: a molecular dissection of Aα immunogenicity. Cell (1986) 47, 173-181.

A. Dorn, J. Bollekens, A. Staub, C. Benoist and D. Mathis: A multiplicity of CCAAT box-binding proteins. Cell (1987) 50, 863-872.

W. van Ewijk, Y. Ron, J. Monaco, J. Kappler, P. Marrack, M. LeMeur, P. Gerlinger, B. Durand, C. Benoist and D. Mathis: Compartmentalization of MHC class II gene expression in transgenic mice. Cell (1988) 53, 357-370.

J. Böhme, K. Haskins, P. Stecha, W. van Ewijk, M. Lemeur, P. Gerlinger, C. Benoist and D. Mathis: Transgenic mice with I-A on islet cells are normoglycemic but immunologically intolerant. Science (1989) 244, 1179-1183.

L.J. Berg, A.M. Pullen, B. Fazekas de St. Groth, D. Mathis, C. Benoist and M.M. Davis: Antigen/ MHC specific T cells are preferentially exported from the thymus in the presence of their MHC ligand. Cell (1989) 58, 1035-1046.

C. Benoist and D. Mathis: Positive selection of the T cell repertoire: where and when does it occur? Cell (1989) 58, 1027-1033.

P. Dellabona, J. Peccoud, J. Kappler, P. Marrack, C. Benoist, D. Mathis: Superantigens interact with MHC class II molecules outside the antigen groove. Cell (1990) 62, 1115-1121.

J. Böhme, B. Schuhbaur, O. Kanagawa, C. Benoist, D. Mathis: MHC-linked protection from diabetes is not due to clonal deletion of T cells. Science (1990) 249, 293-295.

D. Cosgrove, D. Gray, A. Dierich, J. Kaufman, M. Lemeur, C. Benoist, D. Mathis: Mice lacking MHC class II molecules. Cell (1991) 66, 1051-1066.

S. Viville, J. Neefjes, V. Lotteau, A. Dierich, M. Lemeur, H. Ploegh, C. Benoist, D. Mathis: Mice lacking the MHC class II-associated invariant chain. Cell (1993) 72, 635-648.

Richard Won Park

Education

Brown University Providence, RI August 1998 – May 2002

- Concentration: **Computational Biology Sc.B.** GPA: 3.4/4.0
- **Relevant Courses:** Computational Molecular Biology, Computer Graphics, Database Management Systems, Computer Systems, Algorithms and Data Structures, Organic Chemistry, Biochemistry, Genetics, Biotech. & Medicine, Biotech. Management.

Computer skills

LINUX, UNIX, JAVA, C++, S-PLUS, R, Visual Basic, HTML, SQL, Quark XPress, Microsoft Access, Macromedia Flash, Freehand, & Dreamweaver, Adobe PhotoShop, Illustrator, Microsoft Office

Work experience

Joslin Diabetes Center Boston, MA Sept 2002 – Present

Computational Data Analyzer – Helping various researchers deal with data analysis as well as creating computer tools to analyze various types of experiments. Implemented a statistics language with a visual basic interface to analyze micoarray experiments as well as adapting virtual reality for flow cytometry analysis. Targets: Diabetes, Arthritis, T-cell development (Autoimmunity).

Brown University (SciVis) Providence, RI May 2002 – Aug 2002

Research Assistant – Developed with a researcher from Los Alamos to implement a real time 3D rendering algorithm (R OAM) to use satellite data from NASA to create a virtual reality world of the North Pole of Mars.

Epivax Providence, RI Dec 2001 – May 2002

Research Assistant – Incorporated an older algorithm (AMPHI) with their current program of T-cell epitope detection. The goal is to detect other epitopes not detected with their current algorithm as well as decreasing the number of false positives to be tested in vitro for vaccine development. Targets: HIV and TB

Interface Digital Media **New York, NY** **Sep. 2000 – Feb. 2001**

Web Designer – Helped design and develop clients' sites ranging from HTML, graphics, Macromedia Flash development, and layout.

Hospital for Joint Diseases **New York, NY** **June 2000 – Aug. 2000**

Summer Intern – Received a grant from the National Science Foundation to create a research center's web site, helped in multimedia productions, attended weekly research seminars, and presented progress reports throughout the summer.

Volunteer experience

Dana Farber Cancer Institute Boston, MA Feb 2003 – Present

Blum Resource Center Volunteer – Help provide treatment, disease, and post treatment information to cancer patients as well as providing a sympathetic perspective.

Boston Meals for Communities Boston, MA Spring Break 2000

Helped organize students, prepare, deliver, and cook food for impoverished AIDS patients.

MANNA Philadelphia, PA Spring Break 1999

(Metropolitan AIDS Neighborhood Nutrition Alliance) Helped prepare, cook, and deliver food to AIDS patients in and around economically challenged areas of Philadelphia.

Curriculum Vitae - Guillaume Marceau

965 Grant, Longueuil, Québec, J4H 3J8
450-670-3617, gmarceau@cim.mcgill.ca

/** Profile ***

Computer science graduate with demonstrated ability to deliver. Experience includes: three Pan-American competitions, contributions to two different academic research teams, and several programming contracts. Proficient C++, Java, Scheme and Ocaml programmer. Excellent academic background with strong focus on research. Specialized in Ai/Robotics and Compiler/Programming language design.

/** Selected Accomplishments ***

. Head coder for McGill at Sony's International Robocup Competition.

. Built three compilers: one web language, one circuit design language and one concurrent control language.

. Authored Micropouce, the geomatic carpooling matcher in use by Bell Canada, Trizec Hann and the Charles-Lemoyne Hospital.

/** Education ***

B.Sc. Computer Science, CGPA 3.4/4.0- June 2001
McGill University, Montreal
DEC Pure Sciences - May 1997
Cegep Edouard-Montpetit, Longueuil
Languages : Native French, fluent English, beginner German

/** Relevant Books Read ***

. The Mythical Man-Month, by Frederick P. Brooks
. Code Complete, by Steve C. McConnell
. The Deadline, by Tom Demarco

/** Awards and Fellowships ***

Natural Sciences and Engineering Research Council of Canada (NSERC) Undergraduate Award (2x5000$) - 1998 and 1999

First place, Programming Contest of McGill's ACM Chapter - Oct 1998

First place, AAAI's Find Life on Mars Challenge, Madison, USA - Aug 1998

/** Publications ***

Etienne M. Gagnon, Laurie J. Hendren and Guillaume Marceau. *Efficient Inference of Static Types for Java Bytecode*, published at SAS2000. (21 pages)
http://www.sable.mcgill.ca/publications/#sas2000

Robocupers 2000, Peter Stone, Tucker Balch. *Robocup 2000 : Robot Soccer World Cup IV (Lecture Notes in Computer Science, 2019.).* (pages 627-630)
http://www.amazon.com/exec/obidos/ASIN/3540421858/qid%3D997632263/002-9227105-1196020

Letters of Intent to Collaborate

In general, I confirm that we are quite interested in colaborating with you on the project. Richard Park, a Brown graduate with experience in scientific computing and visualization, will be your primary contact here. He will also help in interfacing with the 2 or 3 lab members who have considerable experience in flow cytometry, and who will be glad to participate in the project. They can help evaluate the tools with real data and biological questions, provide suggestions for the interface aspect of the project, and generally help in defining the scope.
Christophe

I intend to collaborate and work as the primary contact between the computer scientists and the immunologists on this project.
Richard

Visualizing Deep Brain Stimulation Settings in Obsessive Compulsive Disorder Patients

David Eigen – PI
Vadim Slavin Nicholas Yang
Benjamin Greenberg, M.D. Ph.D. Erin Einbinder

October 13, 2003

Abstract

Deep Brain Stimulation (DBS) is a new treatment being applied to Obsessive Compulsive Disorder (OCD) in which electrodes are surgically inserted into the brain. A large part of this treatment is calibration after surgery, where settings for the electrodes are adjusted to find the best long-term response. Complicating matters are the facts that the parameter space is very large, and that chronic responses may take days or more to surface. In this project, we address some of these problems through intuitive visualizations intended to shed light on important relationships between electrode settings and patient response.

1 Introduction

Obsessive Compulsive Disorder (OCD) is an anxiety disorder in which the individual is overcome by fears, anxieties, thoughts or impulses, usually of disturbing things. In response to these obsessions, the individual performs certain acts or rituals, often repetitively. For example, a person fearful of contamination might compulsively wash; a person afraid of starting a fire might have constant impulses to check the stove. OCD is common: it affects over 2% of the national population [3], and most people have experienced some OCD-like symptoms at some point in their lives.

Deep Brain Stimulation (DBS) is a new surgical procedure in which electrodes are placed directly into specific targets in the patient's brain. Electricity is supplied to the electrodes via thin wires that run through the skull and down the neck, connecting to a battery implant and control circuitry in the chest. By introducing an electrical signal in local areas of the brain, it is possible to interfere with brain activity and reduce symptoms. DBS was first used in 1987 and is already an established procedure for treating Parkinson's and related motor diseases. It is now starting to be applied to severe cases of OCD.

The effectiveness of the stimulation greatly depends on the placement, configuration and parameter settings of the electrodes. Without the right settings, DBS will not improve the patient's symptoms,

and may even make them worse. In the current procedure for OCD, two leads are inserted into the brain, each with four electrodes. Each of the electrodes can be set to positive or negative potentials; many more parameters can also be varied, such as pulse width, frequency, amplitude, and current. This large parameter space presents a problem for doctors and technicians: What settings will produce the best chronic response in the patient?

2 Problems and Goals

The primary goal of this collaboration is to create and use visualization tools to find the configurations of electrodes that produce the best chronic responses. The end product will be a set of tools that can be used to research relationships in the data, and communicate those relationships with other researchers. The main questions we must address to find the best configurations are the following:

- *What is the relationship of electrode settings and acute patient response to the chronic response?* Some effects of stimulation might not be seen until days or weeks (or even years) after stimulation with a particular setting begins. Yet these are exactly the long-term responses we wish to improve. Is it possible to use the short-term response and the configuration settings to predict the chronic response? If so, this could help reduce calibration times by allowing acute responses to guide more of the process.
- *What are the effects of varying the anatomical placement of the electrodes?* Variations in placement are most likely a key factor in variation of responses across individuals. How does placement affect the settings needed to produce a given response in the patient? Is there some way to "compensate" for variation in placement using the configuration settings?
- *How reliable are the effects of changing settings?* For a given setting, how much does patient response vary within the same patient, or across different patients? I would expect the acute response may vary within one patient, but the chronic response should always converge to the same result in the long run.

We will address these questions by creating and using visualization tools for desktop computers. We will work mostly on the first problem, relating electrode settings, acute response, and chronic response. If we have time or find it necessary for comparing between patients, we may also address the effects of anatomical placement. In particular, we will focus on the following two specific questions:

- *Are there any acute "predictors?"* Are there any acute responses or side effects to stimulation that might signal a positive long-term response? If so, what are they? Potential candidates include ratings on mood, anxiety, depression, etc., and also side effects such as warmth or tightness in the face.
- *Which is the most important parameter?* Is it amplitude? frequency? pulse width? current? The answer to this question will not only allow doctors to choose better settings, but will

also provide evidence for exactly which areas, tissue types and neuron functions are targeted in an effective DBS configuration.

In addition, use of the tools we create will not be limited to the duration of the project. Researchers will be able to continue using them in the future to investigate and explore the data, as well as to communicate findings with other researchers.

3 Visualization Challenges and Techniques

The visualization component of this project is significant. The challenges facing us include:

- *High dimensionality.* The space of parameters and responses is very large. How do we present the user with all the relevant information in a way that enables them to gain insight into the relationships? How do we let the user find and then specify what the relevant data is? How do we allow the user to navigate through the space?
- *Sparse data.* While there is a fair amount of data, it covers the space only sparsely. This could present problems for some visual representations, especially those that require finer sampling (e.g. generating surfaces or interactively choosing settings with dials). On the other hand, it may benefit other techniques (e.g. glyphs, parallel coordinates).
- *Obscure relationship with chronic data.* We want to find the settings that lead to the best chronic response. But the eventual response is not known until weeks after a session, and by then other settings have been tried out. How can we accommodate this time delay? How can we create meaningful visual associations between long-term responses and data points from adjustment sessions?

Our first visualization tool, to be created in the first two weeks, will employ a simple yet powerful 2D interface (a mockup is shown in the Appendix). In it, the user places and edits components that offer different views of the data. These components use different visualization techniques, and can be interactive. In our first visualization, there will be a coarse-scale graph of patient response over time on the top of the screen. In this graph, the user can specify a time slice — a window in time that he/she is interested in. He/she can then specify and interact with visualizations of patient response and electrode settings, restricted to this time interval. Separate views are linked together by using consistent scales on the x-axis. Multiple patients or time slices can be specified, allowing the user to compare data between patients and times (see Figure 2 of the Appendix).

This visualization addresses the problem of relating acute data to chronic data: by specifying slices in time, the user can identify interesting times in the chronic response, and see what acute events happened in an interval before then. High-dimensionality is addressed by displaying each dimension in an appropriate format, and allowing the user to choose what to show and how to show it. We do not force an unnatural visualization, such as a 2D or 3D scatter-plot of the whole space.

After creating this first visualization, we will decide how to extend and improve the tool through close collaboration. A likely extension is to allow dimensions other than time to be sliced or

displayed on the x-axis. This will allow us to explore relationships between arbitrary variables, which is necessary for determining which parameters are most important. It will also allow us to see which portions of the parameter space have been explored, and which still need to be investigated. Other possible extensions include using parallel coordinates, glyphs, Chernoff faces, animation, videos or pictures of patients' facial expressions, and data from PET, EEG and fMRI. A nice feature of the interface is that it can easily accommodate such extensions (see Figure 3 of the Appendix).

4 Previous Work and Significance

There are very few useful visualization tools for investigating DBS in OCD. Currently, doctors and researchers create plots in Microsoft Excel; there are no visualization tools beyond this. Our visualization tools will most likely be a great help to researchers on both current and future problems, allowing them to make insights that would not otherwise be possible.

In addition, we will find relationships between settings and patient response; in particular, we will aim to identify acute predictors. This will help reduce configuration times. Furthermore, we may also supply evidence for how DBS works by determining which parameters are the most important.

There is much work done on visualizing multivariate and multidimensional data [10, 5, 8]. Usually, however, existing visualization techniques only deal with discrete data points (e.g. dimension stacking, parallel coordinates, scatter-plots). They do not address the problem of relating acute data to long-term chronic response. Thus, while our visualizations will draw on existing methods, we will adapt and create new techniques that address this problem. In addition to this, the project may also result in new user interface techniques for multivariate/multidimensional visualization.

5 Work Plan

For this project, I plan to maintain very close collaboration. We will continuously improve visualization tools, with collaborative evaluations weekly or more often. The implement/evaluate/improve cycle will be repeated as many times as possible, hopefully leading to a useful tool and several answered questions in the psychiatry. In particular, I propose the following plan:

- **Week 1**. We will implement an interface to the database and the visualization framework described in section 3. We will also start to work on components for visualizing the data over time, and collaboratively evaluate the tools so far.
- **Week 2**. We will implement the slice intervals described in section 3, as well as components for line graphs, text, waveforms, and electrode on/off settings. This first tool will be used and evaluated extensively. Based on collaborative feedback, we will decide what to implement and improve in the coming weeks.

- **Weeks 3-4**. We will improve techniques for comparing between different times and patients. We will also investigate other visualization techniques and extensions as described in section 3.
- **Weeks 5-6**. Development and touch-up of final tools. This will involve a feature freeze, cleaning up and possibly doing more integration for what we have. We will create user documentation for the tools, and produce write-ups of the software, techniques used and new findings.
- Throughout the course of the project, we will use the tools to find acute predictors and to see which stimulation parameters matter the most.

6 Participants

Our team spans a wide range of experiences and backgrounds necessary for this project. Benjamin Greenberg is a leader in the fields of DBS and OCD. Erin Einbinder is also experienced in these areas, and knows the details of the patient data. Vadim Slavin has a solid physics background, which is necessary for understanding the electric stimulation and its effects. Nicholas Yang and David Eigen have graphics and user interface experience, as well as backgrounds in cognitive science and mathematics.

References

[1] William S. Cleveland and Robert McGill. Graphical perception and graphical methods for analyzing scientific data. *Science*, 229:828–833, 1985.

[2] Benjamin D. Greenberg, Mark S. George, Juliet D. Martin, Jonathan Benjamin, Thomas E. Schlaepfer, Margaret Altemus, Eric M. Wassermann, Robert M. Post, and Dennis L. Murphy. Effect of prefrontal repetitive transcranial magnetic stimulation in obsessive-compulsive disorder: A preliminary study. *American Journal of Psychiatry*, 154(6):867–869, 1997.

[3] Benjamin D. Greenberg, Lawrence H. Price, Scott L. Rauch, Gerhard Friehs, Georg Noren, Donald Malone, Linda L. Carpenter, Ali R. Rezai, and Steven A. Rasmussen. Neurosurgery for intractable obsessive-compulsive disorder and depression: critical issues. *Neurosurgery Clinics of N America*, (14):199–212, 2003.

[4] Benjamin D. Greenberg and Ali R. Razai. Mechanisms and the current state of deep brain stimulation in neuropsychiatry. *CNS Spectrums*, 8(7):522–526, 2003.

[5] Christopher G. Healey and James T. Enns. Large datasets at a glance: Combining textures and colors in scientic visualization. *IEEE Transactions on Visualization and Computer Graphics*, 5(2):145–167, April-June 1999.

[6] T.J. Jankun-Kelly and Kwan-Liu Ma. Visualization exploration and encapsulation via a spreadsheet-like interface. 2001.

[7] Claire Knight and Malcolm Munro. Mindless visualizations. In *6th ERCIM Workshop: User Interfaces for All*, October 2000.

[8] David A. Rabenhorst. Interactive exploration of multidimensional data. 1993?

[9] James S. Tittle, David D. Woods, Axel Roesler, Martin Howard, and Flip Phillips. The role of 2d and 3d task performance in the design and use of visual displays. In *Proceedings of the 2001 Human Factors and Ergonomics Society Meeting*, 2001.

[10] Pak Chung Wong and R. Daniel Bergeron. 30 years of multidimensional multivariate visualization, 1997.

Appendix

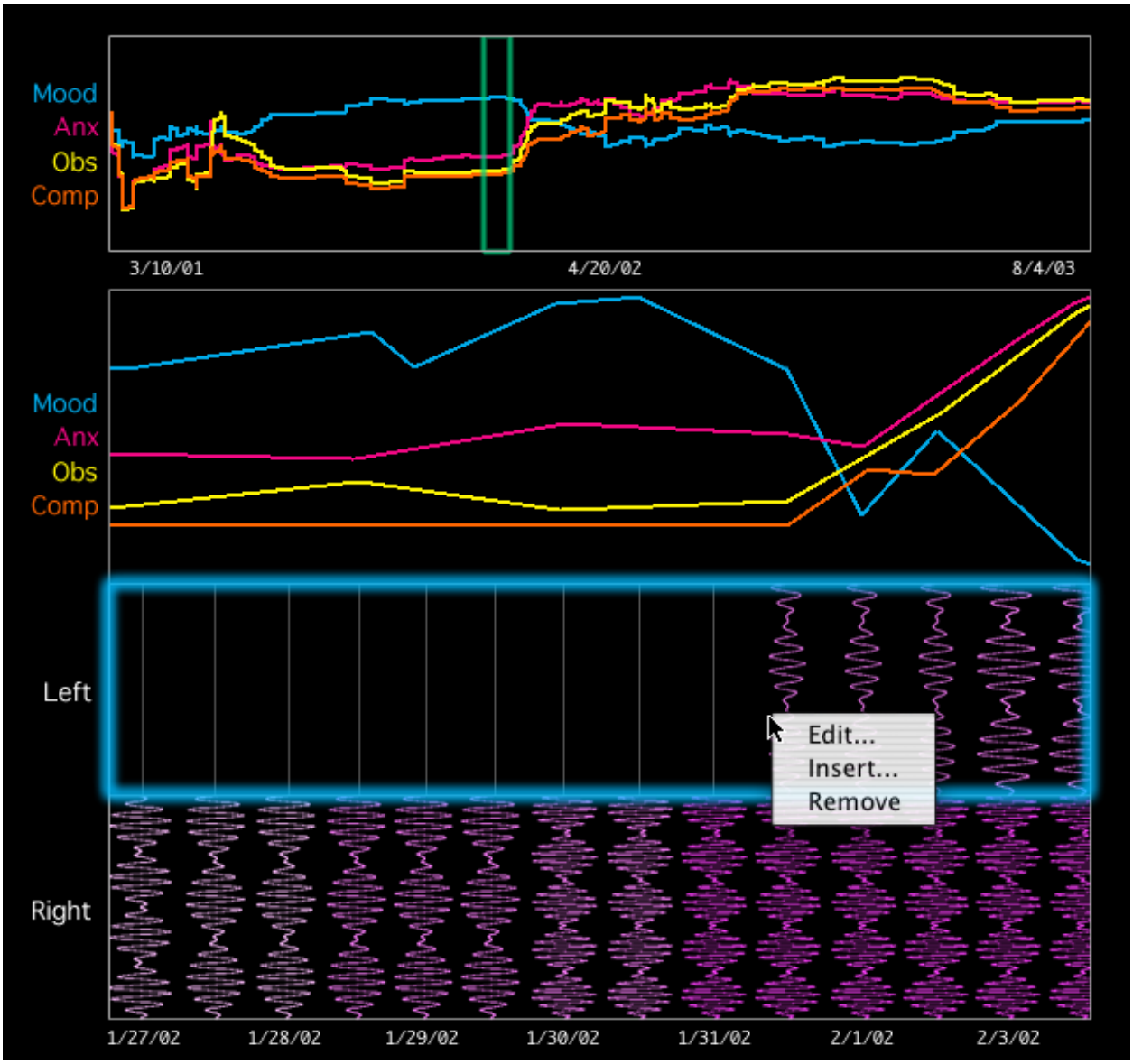


Figure 1: A potential visualization interface. The user can specify a time slice in the coarse-scale timeline above. Acute data for this slice is shown in the lower portion of the screen. The user can specify settings on how to display the data. Waveforms are used to convey electrode parameters.

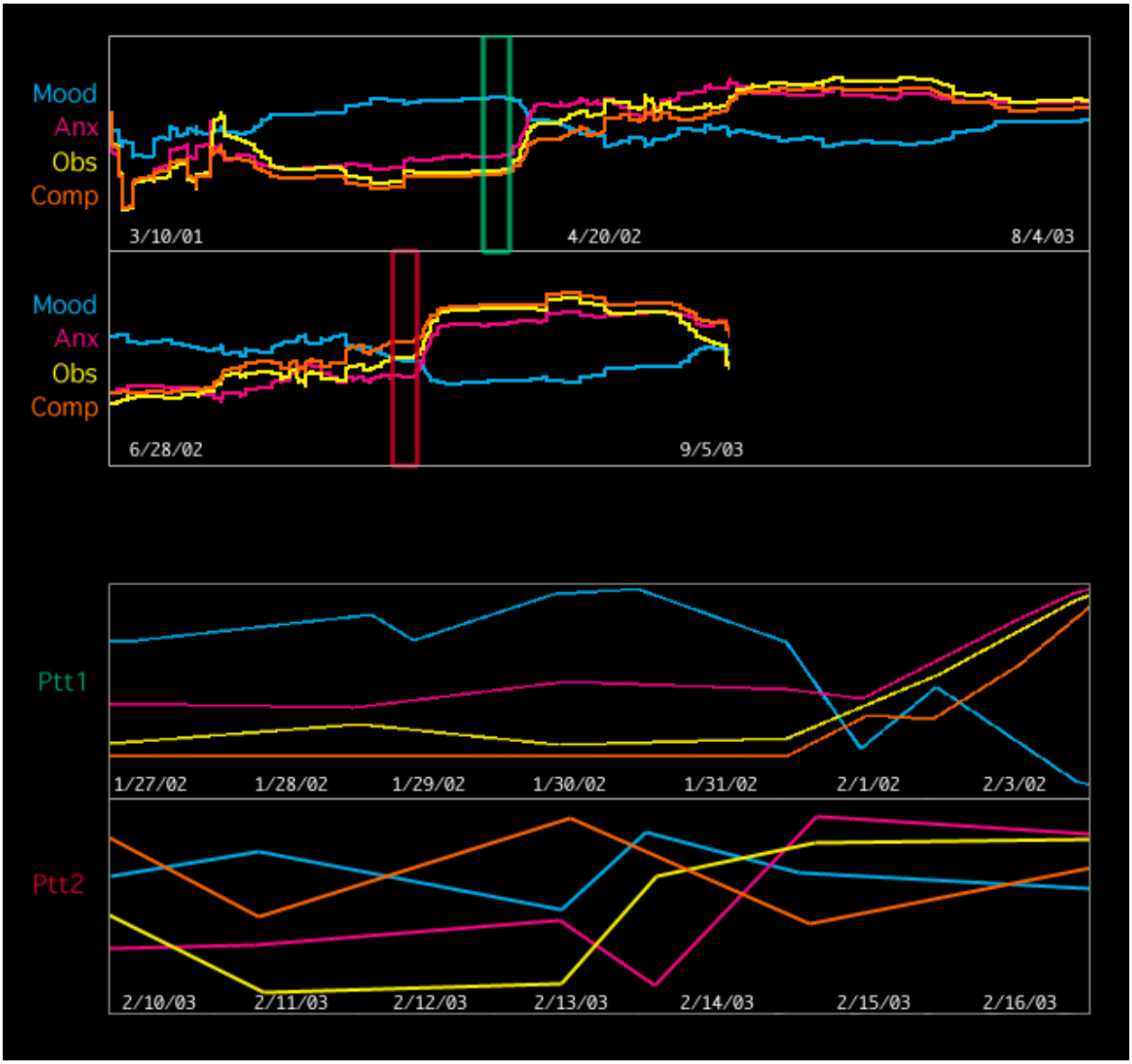


Figure 2: The same interface can be used to compare different time slices between patients. Note the time scales remain consistent across components.

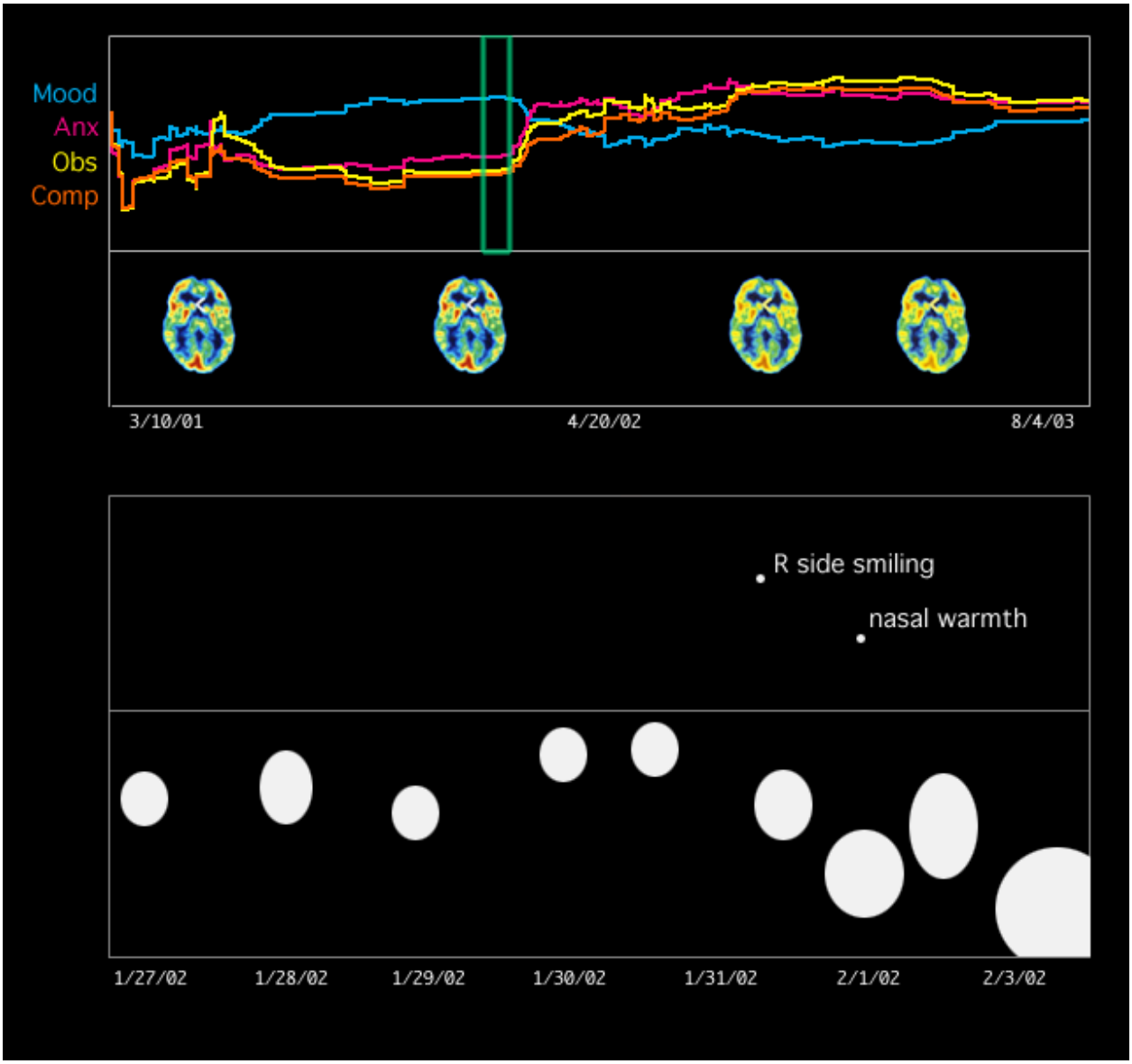


Figure 3: Many different types of data and visualization techniques can be integrated.

David Eigen – PI

Email: deigen@cs.brown.edu

Education

Sc.M. candidate, Brown University
Sc.B. in Mathematics – Computer Science, Brown University, 2003

Research and Professional Experience

- Ongoing work with Prof. Banchoff since Summer 2000 developing software tools for creating interactive visual demonstrations, mostly for differential geometry and calculus. This software is currently used by both students and instructors in differential geometry, calculus, linear algebra, geometry and analysis courses at Brown.
- Teaching Assistant, CS 224 (Interactive Computer Graphics), Spring 2003
- Teaching Assistant, CS 173 (Programming Languages), Fall 2002

Relevant Skills

- Strong programming, computer graphics and user interface skills
- Strong mathematics background
- Experience in cognitive science

Vadim Slavin – Co-PI

Email: vslavin@cs.brown.edu

Education

Sc.M. candidate, Brown University
Sc.B. in Math-Physics, Brown University, 2002
A.B. in Computer Science, Brown University, 2002

Research and Professional Experience

- Software Consultant, Linkit Inc., Providence RI, June 1999 - present
- Software Engineer, Orbidex Inc., Providence RI, March 2000 - June 2001

Relevant Skills

- Strong physics background
- Strong programming skills
- Experience in mathematics

Nicholas Yang – Co-PI

Email: nyang@brown.edu

Education

Sc.M. candidate, Brown University
Sc.B. in Computer Science, Brown University, 2003

Research and Professional Experience

- Software Engineer, Brown University Computer Science Graphics Group, Summer 2003
- Software Engineer, Pegasystems, Summer 2001
- Software Engineer, DYS Analytics, Summer 2000
- Webmaster, YMAA Publication Center, Summer 1997

Relevant Skills

- Strong programming skills
- Experience with user interface design in CAVE
- Computer graphics knowledge

Benjamin Greenberg, M.D. Ph.D. – Collaborator

Email: bdg@butler.org

October 10, 2003

To: David Eigen
From: Ben Greenberg, MD, PhD
Re: CS 237 project

As we have discussed, I will be delighted to collaborate with you on this very interesting project investigating the relationship between acute responses to deep brain stimulation and therapeutic response to chronic stimulation in neuropsychiatric patients.

Education

University of Miami, M.D. 1987
University of California, San Diego (UCSD), Neurosciences, Ph.D., 1984
Amherst College, Psychology, B.A. 1978, magna cum laude

Selected Publications

Greenberg BD, Price LH, , Rauch SL, Jenike M, Malone D, Friehs G, Noren G, Rasmussen SA. Neurosurgery for Intractable Obsessive-Compulsive Disorder and Depression: Critical Issues. Neurosurgery Clinics of North America, 2003; 14(2):199-212.

Greenberg BD. Update on Deep Brain Stimulation. Journal of ECT 2002;18(4):193-6.

The OCD-DBS collaborative group. Deep brain stimulation for psychiatric disorders Neurosurgery, 2002, Volume 51(2): 519.

Hoehn-Saric R, Schlaepfer TE, Greenberg BD, Daniel R McLeod DR, Pearlson GD, Wong SH. Cerebral bloodflow in obsessive-compulsive patients with major depression: effect of treatment with sertraline or desipramine on treatment responders and non-responders. Psychiatry Research 2001;108 (2):89-100.

Wasserman EM, Greenberg BD, Nguyer M, Murphy DL. Motor cortex excitability correlates with an anxiety-related personality trait. Biological Psychiatry 2001; 50(5): 377-382.

Erin Einbinder – Collaborator

```
Date: Fri, 10 Oct 2003 15:43:34 -0400
From: Erin_Einbinder@brown.edu
To: David Eigen <deigen@cs.brown.edu>
Subject: Re: CS 237 project

I would be happy to collaborate.
```

Skills and Experience

- Experience in DBS and OCD
- Knowledge of patient data
- Experience in psychiatry and psychology
- Skills in chemestry and organic chemistry

Sociological Visualization

A CS237 project by

Daniel Grollman (Computer Science)
Katherine Cannon (Sociology)
Jason Mallios (Computer Science)
Stephen Redihan (Computer Science)

With consultants
Anne Dill (Sociology)
Phil Brown (Sociology)

Abstract:

Sociological research depends on statistical analysis of qualitative data to draw inferences about societal interactions. However, finding these relationships in the resulting numbers and graphs is a difficult task, and results are often open to multiple interpretations. We seek to develop a new visualization technique to aid in the analysis of sociological data.

Overview:

In the last 50 years, sociology has undergone several revolutions in the methods it uses to collect and analyze data. The focus of these revolutions has traditionally been on developing better statistical methods, from cross-tabulation to regression analysis, for analyzing empirical data drawn from multiple sources, such as surveys or interviews.

However, reducing such human-generated data to a series of numbers and performing statistical analysis on it, which usually results in a bar chart or a pie graph, necessarily hides some of the data. Efforts to include more data in the resulting analysis results in overly complicated, hard to understand graphs.

We believe that new visualization techniques need to be developed to help researchers visualize the growing amounts of data they acquire. Such visualizations will take advantage of the recent advances in computer graphics and scientific visualization.

Organizational theory is a sociological theory that describes the interactions between groups of people, usually within the construct of an organizational structure. A new study in the application of organizational theory to healthcare in the US has been undertaken, which will result in survey and interview data for ~100 people. While normal statistical means will produce an answer as to whether or not US healthcare conforms to organizational theory, new visualization methods will be developed to do the same. The visualizations can either agree or disagree with the statistical analysis. Either way, we hope to bring to light new relationships within the data, perhaps leading the way to new statistical methods, and new ways of thinking about sociological information.

Methods:

Sociological surveys will be distributed to ~50 patients and ~50 physicians in 3 Providence, Rhode Island area hospitals. In addition, ~10 patients and ~10 physicians will be interviewed. The results from these interviews and surveys will form the data set for the 'testing' portion of the study. In addition, survey and interview data from previous sociological studies is available. This data will serve as the data set for the 'training' portion of the study. By having different data sets for training and testing, we hope to force our techniques to be generalizable.

The data from both sets will be subjected to normal sociological statistical analysis, but in addition it will be visualized using new techniques. We will investigate if the new visualizations make relationships in the data easier to determine.

The new visualizations will take many forms, from augmented bar charts to fully immersive 3D rendering of people and the relationships between them. To develop the visualizations, we plan to take advantage of the unique equipment and expertise available at Brown University.

In the Cave, a 4 wall immersive 3D environment, there has been developed a technique for prototyping 3D visualizations for multi-valued data. We would like to use this to sketch out possible ideas for visualizations. One such idea is to have each person in the survey/interview data represented by their own icon, which could be colored, sized, shaped and placed in relation to other icons to represent the different measured values in the data, such as speed of service, satisfaction with their care, etc. 'Emoticons' can even be used, making a more intuitive connection between a person's satisfaction and their representation in the visualization. (see figure 1)

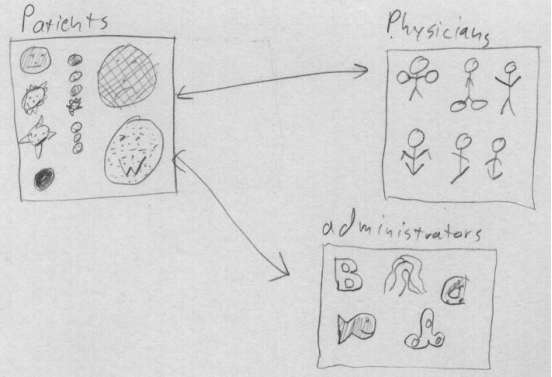


Figure 1: A sketch of possible visualization techniques. In this sketch, values such as patient satisfaction, physician's ability, and 'red tape' are mapped to varying degrees of size, shading, and shape. In 3D color representations, many more variables can be mapped to many more iconic representations.

Such a representation would utilize more of a person's visual pipeline to input data. Most statistical charts (graphs, pies, numbers), only represent one or two, or possibly three different variables, and even then they do it in a non-intuitive manner, linking the color of a bar on a bar graph to a year of gathered data. By linking colors, shapes and distances to data in a more intuitive manner (warm colors to warm feelings, distance to personal separation, etc), the data will be made more understandable, to non-sociologists as well as sociologists.

Developing the appropriate icons for use in the visualizations will be difficult, and for this reason we will take advantage of another technique in the cave. Developed by Vote and Laidlaw, there is a method where the researcher selects an oil painting that has appropriate compositional elements (lines, brushstrokes, splotches) for representing their data, and the system then develops a mapping from their data to these elements. This saves the researcher the trouble of inventing appropriate icons and other compositional elements. Instead, they can borrow from the masters.

Using both of these techniques, we plan to quickly develop and test several different visualization techniques for the testing data sets. The most useful ones will be further developed and refined, and their utility as a sociological tool will be evaluated and compared with that of straight statistical analysis.

The Group:

To undertake this interdisciplinary project, a sufficiently interdisciplinary team has been assembled. Katherine Cannon, a Sociology masters student, will be heading up the sociology aspect of the project. Guided by her advisors, Drs. Anne Dill and Phil Brown, she will distribute the surveys and conduct the interviews. In addition, she will help in the analysis of the previous study data that we use. Daniel Grollman, a Computer Science PhD student, has significant programming experience, as well as a background in the visual arts (photography and drawing). Jason Mallios, another CS PhD student, brings experience with graphics libraries to the team, which will be most useful in making graphical visualizations. Steven Redihan, the third CS PhD student on the team, brings in additional art experience, as well as a strong background in statistics and probability. All the researchers share an interest in interdisciplinary collaboration, and in the visualization of abstract data.

As mentioned before, we plan to make use of special equipment available at Brown, particularly the Cave, a 4 walled immersive environment. In addition, we have access to several 'fishtank' systems, which are computer monitors equipped with head-

tracking equipment and shutter-glasses for stereo imaging, and a virtual desktop system. All of these offer intriguing possibilities for visualizations.

For the sociological side of the experiment, Brown University is situated in Providence, RI, where there are several hospitals, providing the population to be surveyed about healthcare. A large enough population will ensure statistically significant results.

For the actual programming of the visualization, each CS PhD student has access to their own high-end workstation, equipped with UNIX, as well as several departmental machines available for common use. And, for the visualization research itself, the people who developed the techniques(cave painting, art-templates) are available for consultation.

Work Plan:

Week1: Prototype visualizations in the Cave.

Week2: Further develop the visualizations, applying them to different data sets to ensure generality.

Week3: Refine and code up the final visualization.

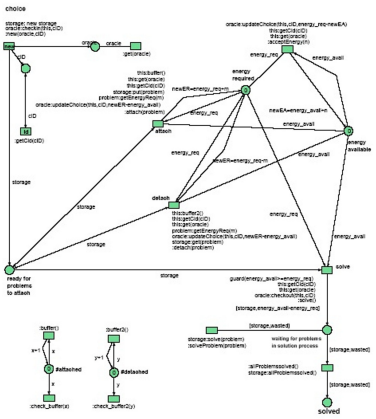
Week4: Apply the visualization to the Healthcare data set, draw conclusions and compare with normal statistical evaluation.

Week5: Adapt visualization for other systems (fishtank, workstation, etc) if appropriate.

Week6: Write-up/ leeway for last minute fixes and tests.

Significance:

Sociologists these days deal with large volumes of empirical data, gleaned from surveys and interviews. Analyzing this data through statistical means necessitates the hiding of some of the data, for ease of view. In addition, isolating the necessary relationships in the data is an arduous task. Visualizations are important to this work, making the relationships easier to view. Current sociological visualizations are limited to bar charts, pie graphs, and reference nets (see figure 2). The proposed work will give rise to new, 3D visualizations to aid the sociological researcher in their work. A study on the application of Organizational Theory to Healthcare in the US will serve as the test bed for these new visualizations. By providing a new way of looking at the relationships in the data, new inferences will be able to be drawn, and possibly give rise to new methods of statistical analysis.



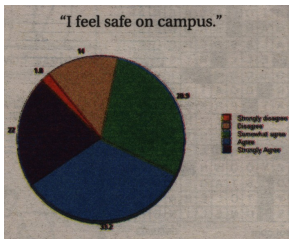


Figure2: Sample visualizations from sociological studies. Left, a reference net, representing the interactions of groups of people. Right, a pie chart showing perceived safety on campus.

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Michael Köhler, Roman Langer, Daniel Moldt, and Heiko Rölke. Combining the sociological theory of Bourdieu with multi agent systems. In Modeling Artificial Societies and Hybrid Organizations (MASHO'00), Workshop at the ECAI http://citeseer.nj.nec.com/ohler00combining.html

David Karelitz and Daniel Keefe and David H. Laidlaw, Using CavePainting to Create Scientific Visualizations, 2003

Daniel H. Grollman

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Education

2003-Present **Brown University**
PhD student in Computer Science

1999-2003 **Yale University**
Bachelor of Science: Electrical Engineering and Computer Science

Previous Employment

June - Aug '03 **Microsoft,** Software Design Engineer.
Supervisor: Gerry Cermak
- Design and implement P2P protocols for SPOT (Smart Personal Object Technologies)

Sep '01–May '03 **Yale University Department of Computer Science**, Robotics Researcher.
Supervisor: Dr. Brian Scassellati
- Design, build, program, test and work with humanoid robots to test theories of social learning.

June - Aug '02 **Microsoft Hardware,** Intern Firmware Engineer.
Supervisor: Mark Hanson
- Wrote firmware for use in wireless products. Dealt with issues of RF interference, USB/PS2 communications, and usability.

May - Aug '01 **University of Edinburgh Division of Informatics,** Researcher.
Supervisor: Dr. Gillian Hayes
- Wrote code to interface several existing projects into a mobile robotic system that could recognize and react to human arm gestures, using no special equipment.

Jan - May '01 **Yale University Department of Computer Science**, Teaching Assistant.
Supervisor: Dr. Paul Hudak
- Wrote and maintained code for use in the autonomous systems course.

May '00 - Jan '01 **Yale University Department of Computer Science**, Research and Design
Supervisors: Drs. Paul Hudak, John Peterson, and Drew McDermott
- Was part of the team that represented Yale at the Robocup 2000 competition in Melbourne, Australia. Expanded Haskell FRP (Functional Reactive Programming) for use in the competition.

Oct '99 - May '00 **Yale University Physics Department**, Research Assistant.
Supervisor: Dr. Satish Dhawan
- Assisted in the design of circuit boards to do real-time analysis of particle collision data using FPGAs (Field Programmable Gate Arrays).

1998-1999 **Cornell University Medical Center**, Researcher.
Supervisor: Dr. W. A. Muller
- Designed and performed experiments to study biological processes involved in inflammation.

Skills

- Programming Languages: C, C++, BASIC, PowerBASIC/DLL, Java, Haskell functional programming, Perl, Assembly.
- Experienced in developing and designing protocols and experiments for use in medical, electrical and robotic laboratories.

Awards

1999 Intel Science Talent Search Finalist. (Formerly the Westinghouse)
Honor Student at the American Academy of Achievement's Banquet of the Golden Plate
Finalist in the Lucent Global Science Scholars Contest
National Merit Finalist

Jason Mallios
30 Beaufort Street, Apt. 2B
Providence, RI 02908
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SUMMARY: Web programmer, Brown University Master of Computer Science student.
Skills: ASP (Classic and .NET), Cold Fusion, PHP, DBMS (Access, SQL Server), Visual Basic, C, C++, Java, Perl, JavaScript, DHTML, CSS, SSL, Visual Studio, Photoshop, Illustrator, Pagemaker, Quark Xpress, Dreamweaver, Flash, Fireworks.
Environments: Windows / IIS, UNIX AIX / Apache, Mac, Linux.

WORK EXPERIENCE
Web Designer, The University of Texas System Administration-Employee Group Insurance (EGI) (2/00-6/03; reclassified from Graphic Designer 9/02)

- Designed and programmed group insurance Web site, www.utsystem.edu/egi, for 80,000 subscribers, and their dependents, at 15 campuses statewide. This W3C-accessible site receives between 6,000 and 30,000 unique visitors a month and is implemented with an underlying DBMS, server- and client-side scripts, and style-sheets.
- Worked with customers to design and build a secure Web-based publication-ordering and reporting system for campus HR offices and printing vendors. The system requires SSL logon, publication submission and ordering, and various public, private and user-specific reports.
- Laid out, edited, prepared for press, and arranged delivery of 4-color publications to campus HR offices and members.
- Successfully managed a $120,000 to $170,000 annual printing budget.

Project Lead, Austin Telecommunity Project Network, Austin, TX (Spring 2002)

- Managed the development of an online course catalog for non-profit group in conjunction with a Software Engineering course.

Electronic Communication Committee Member, KOOP radio, Austin, TX (2001)

- Part of a volunteer team that installed a server for streaming broadcasts of non-profit radio station.

Control Clerk, University of Texas System Administration-EGI (6/99-2/00)

- Researched and analyzed data disparities reported by members or HR offices and recommended manual and programmatic solutions.
- Created tutorial intranet Web site for Control Clerks.

EDUCATION
Master of Science, Computer Science, Brown University (in progress)
Certificate of College Credit in Computer Science, St. Edward's University (2000-02)
Bachelor of Arts in Liberal Arts specializing in English and philosophy, St. Edward's (1995-97)
Archaeology Study Abroad, Universidad de Querétaro, Querétaro, México (Summer 1995)

RESEARCH
Algorithms and complexity theory, human-computer interface, Brown University (Fall 2003)
W3C accessibility study of www.utsystem.edu/egi (2002-2003)
Study of Python's grammar, binding, typing and object-oriented implementation (Spring 2002)
Linear transformations in an Open GL rendering (Fall 2001)
Comparison of bandwidths from 4 different nodes of cable ISP in South Austin using analysis of variance (Fall 2001)
DBMS queries (Fall 2001)
Swing vs. AWT in Java (Summer 2001)

Katherine L. Cannon
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Providence, RI 02906
Tel : (609) 577-4971
e-mail**:** Katherine_Cannon@Brown.edu

EDUCATION

Brown University, Providence, RI
BA International Relations and
Modern US History, May 2003
GPA: 3.6

Brown University, Providence RI
MA Sociology/Organization Studies,
expected May 2004

The Lawrenceville School, Lawrenceville, NJ
Graduate, June 1999 *Cum Laude*

SAT I scores: math- 670, verbal- 620
SAT II scores: Writing- 750,
Chemistry-750, French-720

Related Coursework: Multivariable calculus, Statistics, Political Science, Management of Industrial and Non-Profit Organizations, Biomedical Ethics, Chemistry (Physical and Organic), French Literature

WORK EXPERIENCE

Governor's Program in Fiscal Fitness, Providence, RI **Fall-Winter 2003**

- Three month internship in budgetary analysis program for the RI Department of Health and Human Services
- Assisted team leaders in coordinating projects, gathering and analyzing data
- Consulted and gave recommendations for specific health related policy initiatives

Princeton Management and Development Institute (PMDI), Lawrenceville, NJ **Summer 2002**

- Assisted in coordinating global organization development projects for clients (Aventis Pharmaceuticals)
- Lead data collection and feedback for one global project team development process

Essex County Superior Court, Newark, NJ **Summer 2002**

- Six week Internship under Judge Petrolle and Judge Falcone
- Assisted attorneys in filing motions, preparing legal briefs, and in obtaining documents for court proceedings such as extraditions, sentencings, pre-trial conferences, pre-sentencing investigations and trials

The Leaders Edge, Bala Cynwood, PA **Summer 2001**

- Planned and executed a *Survey of Teenagers' Perceptions of Leader Behavior*
- Surveyed 400 adolescents, compiled and analyzed data and presented findings to corporate executives and school administrators

United Nations in Geneva (NYU Program), Geneva, Switzerland **Summer 2001**

- Three weeks assisting members of UNCTAD in reviewing Ecuador's budget proposal and projections for 2002-2003 fiscal year
- Systematically analyzed fundamental problems in Ecuador's successful allocation of funds to healthcare and education

United Nations, New York, NY **Summers 1999 & 2000**

- Intern for UN Security Council Sanctions Committee

INDEPENDENT RESEARCH

Independent Research Study in Post-Cold War Global Security **Spring 2002**

- Proposed, planned, conducted an in-depth and comparative analysis of Cold War Conflict Resolution to Post-Cold War Crisis Management
- Employed a "case-based" analytic approach; examined how Post-Cold War policy makers focus on *managing*, rather than *resolving* crises

William Bouton Welles Award and Research Grant **1998-1999**

- Received grant for proposal to research and compare Health Issues and Healthcare for Adolescents in US, France and Peru
- Designed and planned surveys of teens and interviews of healthcare providers in the three countries
- Analyzed, compiled and reported results of study to faculty and Board of Trustees of Lawrenceville School and Robert Wood Johnson

3D Immersive Visualization of Topological Defects in Nematic Liquid Crystals

Vadim Slavin
Principal Investigator
Department of Computer Science, Brown University

Jason Mallios, Dmitri Lemmerman
Co-Principal Investigators
Department of Computer Science, Brown University

Robert Pelcovits
Consultant
Department of Physics, Brown University

David Laidlaw
Consultant
Department of Computer Science, Brown University

Abstract

The goal of this project is to develop new techniques for visualization of topological defects in nematic liquid crystals. The development of better liquid crystal based technologies relies on knowledge about the origin and the evolution of defects in such a liquid crystal structure. We propose to develop novel approaches to the research of liquid crystals by visualizing the liquid crystal model in a 3D immersive environment and interactively analyzing such visualization on the subject of presence of topological defects. Furthermore, we will research possible techniques for visualization of evolution of these defects in our modeled system.

Introduction:

There exists a special type of matter called Liquid Crystal (LC) that exhibits the behaviors of both liquid and crystal phases of matter. The molecules of such compounds are elongated, relatively rigid structures that can be approximated as rods in a computer simulation. The alignment of the molecules relative to each other is responsible for different phases that this matter can exhibit. Furthermore, the relative orientation of molecules can be affected by such conditions as intermolecular interactions, temperature and electro magnetic field fluctuations. The latter condition is used to manipulate the liquid crystal compound in order to utilize it's ability to be transparent or opaque to light.

In some areas, the molecules can develop topological defects. These defects can be viewed as localized irregularities or discontinuities in the preferred orientation of the molecules.[Andrienko, 1999] When the nature and behavior of these defects is understood, better technology can be created. This is one of the motivations that drives the current research in topological defects in liquid crystals.

Current methods of research include a computer simulation of a cluster of LC molecules based on molecular dynamics. The simulation computes the state of the system at sequential time steps and further uses this data to advance the simulation for the next set of time steps. This state of the system is described by position and orientation of each molecule in the system. With this information the researchers are able to look at where the topological defects might occur at every time step, and see how these topological structures evolve with time and respond to changing physical parameters around the system. The success of such approach greatly depends on the ability to visualize this data set and make accurate analysis based on such findings.

Goals:

We propose to develop new ways to visualize a large liquid crystal model composed of individual molecules. In particular, we intend to apply both existing and newly developed techniques to visualizing and interacting with a large data set of LC molecules. Our research approach is intended for the betterment of the study of topological defects in such model. The motivation for this is to allow researchers investigate the LC model as a result of their computer simulation and analyze it on the subject of topological defects, their origin, behavior and evolution throughout the lifespan of the simulation. *Our hypothesis is that novel immersive visualization techniques would allow the researchers to find the topological defects, identify their type, and predict their behavior based on interactive visual analysis.*

More specifically, we propose to develop new interaction techniques based on the existing approach of tensor field visualization. By extending the capabilities of user interface of an immersive environment we hope to achieve better interactivity and usability of a visualization system. Keeping this goal in mind we hope to prove our hypothesis as well as show educational value in such interactive modeling of a complex multivalued data model. An audience of observing scientists or students could benefit from such expository visualization .

Significance of Work:

Currently, the visualization techniques do not extend beyond the regular 2D representation of the model and the defects present there (Illustration 1). The preferred orientation of the molecules is visualized using conventional 2D plotting techniques of vector fields, and thus only allow for one layer of molecules displayed at any time. Evidently, there is no way to visualize the system as one whole, and the introduction of other data values, such as individual molecules, would create even more overlap rendering the visualization useless.

Our approach introduces a more flexible visualization system of a model of LC molecules and

subsequent analysis of topological defects present. It can serve as a powerful tool for navigating the output data of the molecular dynamics simulation in a way that hasn't been done before in this area of condensed matter physics. For the first time the user would have the ability to immersively look into the model that he or she is simulating. This software system can also serve educational and instructional purposes.

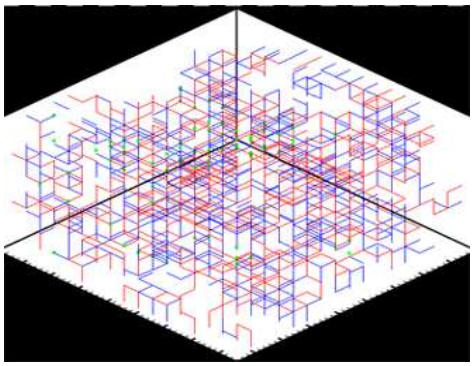

Illustration 1:

Current methods of visualization of topological defects. Shown are the various types of defects occuring at a point in time during the computer simulation.

The ideas behind the proposed visualization translate very well into other areas of applied research where modeled molecular structures simulations are at the core of the research activity. The techniques we propose to develop can serve to better understand the requirements for a successfull 3D vector and tensor field visualization. The preliminary analysis of related work yielded no comparable approach for use of scientific visualization of such kind and we believe that it can provide measurable benefit to Prof Pelcovits's research.

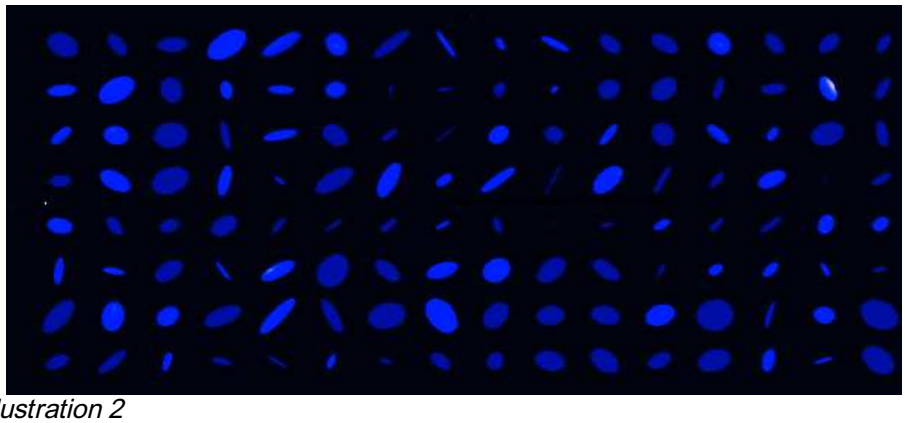

Illustration 2

Layered approach to 2nd order tensor field visualization.
Such layered approach can be utilized to portray tensor-valued field by scaling ellipsoids based on the eigen vectors and corresponding eigen values of the tensor. [Laidlaw, 1998]

Related Work:

The proposed research activity is based on the work of the team under the leadership of R. Pelcovits. The Gay-Berne method of calculating the driving forces of the interactions has been applied to an arbitrary liquid crystal system. The data output of this molecular dynamics computer simulation is used to visualize the network of LC molecules. This data partially consists of the list of position and orientation parameters of every molecule for a set of sequential time steps. For each of

these time steps, the system is subdivided into a 16x16x8 array of bins each of which contains on average 30 molecules. For every bin, the orientation of the molecules is used to calculate the average order parameter tensor. This quantity holds the information about the average orientation of the molecules as well as the amount of order present in this bin. Such data is used in the mathematical algorithms that determine the presence of different types of topological defects. When the output of this algorithm is analyzed for successive time steps of the original simulation, the behavior of these defects is reconstructed. Such analysis of the output of liquid crystal research depends heavily on the ability of physicists to visualize these defects. [Pelcovits,1998]

Another part of this research activity is based on one specific technique for visualization 2nd order tensor field in 3D. (Illustration 2)

Collaborators:

The role of the PI will be to organize the development, systematically manage this project, and serve as the communication bridge between the computer science and physics departments involved. Having a strong background in the general theory of LC structures and defects as well as computer graphics, the PI will serve as the main faciliatator of this activity and offer his knowledge in this area to the rest of the members of investigating team. The PI will also be involved in the development and implementation of the system, dissemination of the results, and gathering user's comments. Dmitri Lemmerman will provide his knowledge of the immersive environment systems and the implementation of the tracking and user interface devices. Jason Mallios will lend his extensive software development expertise. Prof Pelcovits will offer his consulation in the subject of LC as well as provide the team with the output data of his computer simulation. He will also be the chief evaluator of the usability of the system providing useful feedback from the perspective of an active researcher in the area. Prof Laidlaw will provide the results of his investigation of the techniques for visualization of tensor fields in 3D.

Work Plan:

We will structure our goals and milestones around the 6-week timeframe of this project.

- ✔ Week 1: Set up the environment, calibrate the tracking mechanisms, install any necessary software, drivers and assemble a stencil for the software that will be written.

- ✔ Week 2-3: Visualize the model of liquid crystal molecules in an immersive environment using the data from the molecular dynamics computer simulation. We will use the same original approach of binning the system and computing the average order parameter tensor. Our target of visualization will be a simplified system of 16x16x8 second degree tensors. We will use D. Laidlaw's technique for visualizing the 3D field of tensors in the immersive environment.

- ✔ Week 4-5: Apply the power of immersive user interface to develop techniques to better navigate this system of visualized tensors. The goal is to allow the user to judge the system on the amount of order present, on the average orientation of molecules in the bins and across a locus of bins. The user should be able to make predictions on the presence and behavior of defects in the system and thus obtain results similar to those of the mathematical algorithm. For this phase we plan to work closely with Robert Pelcovits's team to jointly approach this subject.

- ✔ Week 6: Incorporate user comments and suggestions for a better expository and educational uses of this system. We will get feedback on the educational value, analyze our results in a final review and propose further areas of exploration.

Facilities:

For the implementation of our project we intend to use an immersive system such as CAVE or

PowerWall. Such systems consist of one or more large back-projected screens with a system of trackers, user interface devices, and stereo goggles. The position of the eyes of the user is tracked for the purpose of producing stereo effect with the help of the goggles and stereo rendering of the scene from the viewpoint of each eye.

Summary:

We believe that the study of liquid crystal matter can directly benefit from applied visualization techniques such as the ones proposed to be developed here. Visualization of resulting data is a critical part of any research activity, especially when such data involves an array of values. An extensive data model is only of any use when there is a clear, manageable, interactive way to present it. This is exactly what this project activity is trying to accomplish - the creation of a three dimensional immersive visual environment for analysis of the results of a LC molecular dynamics simulation.

By combining the results from relevant prior research and our own techniques, we hope to provide a novel data visualization system for researchers studying the nature of topological defects in a liquid crystal model. Beyond the advancement of physicists' research, we expect this powerfool tool be used as an educational resource.

References:

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Laidlaw, David, et al (1998). *Visualizing diffusion tensor images of the mouse spinal cord*. In Proceedings of IEEE Visualization 1998, pages 127-134. IEEE Computer Society Press, October 1998.

Billeter, Jeoffrey, et al (1999). *Phase-ordering dynamics of the gay-berne nematic liquid crystal*. Phys. Rev. E 60

Pelcovits, Robert, et al (1998) *Simulations of liquid crystals*. Computers in Physics, 12.

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Vadim Slavin, Principal Investigator

Personal

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Education:

- 2002 Bachelor of Science in Math-Physics, Brown University, Providence, RI
- 2002 Bachelor of Arts in Computer Science, Brown University, Providence, RI

Related Professional Experience:

-Software Consultant, Linkit Inc, Providence RI - June 1999 to present
-Software Engineer, Orbidex Inc, Providence RI - March 2000 to June 2001

Relevant Courses:
- Software Enginnering, Data Structures, Advanced Computer Graphics, Computer Systems, Virtual Reality
-Advanced Calculus, ODE's, PDE's, Differential Geometry, Complex Analysis, Probability Theory
-Analytical Mechanics, Modern Phyisics, Advanced Physics Laboratory, Physics Thesis Seminar: Defects in Nematic Liquid Crystals.

Related Papers:
-Slavin, Vadim (2002). *Visualization of Topological Defdects in Nematic Liquid Crystals*. Sc.B Honors Thesis, Dept of Physics, Brown University.

Capabilities and skills:
-Strong programming background
-Familiarity with immersive systems such as CAVE
-Strong background and familiarity with OpenGL, WTK, C++, C, java, visual C++, Perl, Visual C++, VB
-Directed knowledge of the research of liquid crystals resulting in undergraduate honors thesis

Jason Mallios, co-Principal Investigator

Personal

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Education:

- 2002 Certificate of College Credit in Computer Science, St. Edward's University
- 1997 Bachelor of Arts in Liberal Arts, St. Edward's University.

Related Professional Experience:

-Project Lead, Austin Telecommunity Project Network, Austin, TX (Spring 2002)

Capabilities and skills:

ASP (Classic and .NET), Cold Fusion, PHP, DBMS (Access, SQL Server), Visual Basic, C, C++, Java, Perl, JavaScript, DHTML, CSS, SSL, Visual Studio, Photoshop, Illustrator, Pagemaker, Quark Xpress, Dreamweaver, Flash, Fireworks.
Environments: Windows / IIS, UNIX AIX / Apache, Mac, Linux.

Dmitri Lemmerman, co-Principal Investigator

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Education:

– 2002, B.A. Computer Science, Brown University, Providence, RI

Related Professional Experience:

-Research Assistant, Brown University, Department of Computer Science, Graphics Group
-Information Technology Intern, Goldman Sachs, Inc.

Capabilities and skills:

Creation of applications from design phase to implementation to post-project analysis. Programming experience in C/C++, Java, Perl, VisualBasic, VBScript, and JavaScript. Graphics programming experience with OpenGL, World Toolkit, Java3D, Qt, and Swing. Scientific visualization and virtual environment implementation using the CAVE environment. Web application implementation using SilverStream, Java Servlets, ASP, CGI, HTML, XML, and XSL. Database experience with SQL Server, Sybase, Oracle, and ADO. Technical experience with Windows NT, Unix (Linux and Solaris), and MacOS environments.

Collaboration Statement from Robert Pelcovits

I am happy to serve as a consultant for Vadim Slavin's proposed scientific visualization project on liquid crystal defects. Vadim has some very exciting ideas regarding this topic which could be of great help to me and my group in understanding the physics of these defects. Vadim has already learned much of the necessary physics background for this project (when he did his senior thesis with me during the 2001-02 academic year), so I think he is very well-positioned to make significant, rapid progress on the visualization. I give my full, enthusiastic support to this proposed work.

R. Pelcovits, Professor of Physics

Collaboration Statement from David Laidlaw

Hi Vadim -

I will be glad to collaborate on your proposal to develop VR visualization capabilities in the Cave for liquid crystal simulations. I expect that we'll be able to come up with some interesting ways to view the data that will help to make flaws more easily found.

Cheers,

-David

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David Laidlaw Associate Professor
Brown Graphics Group Department of Computer Science