Session K – Computer Science
(Alphabetical)

On the Practicality of Fast Modular Composition and Polynomial Factorization over Finite Fields
Arda Antikacioglu
Mentor: Chris Umans

We studied the practicality of the Fast Modular Composition given by Kiran Kedlaya and Chris Umans in a 2008 paper. The algorithm is of great theoretical importance, having the asymptotically best possible runtime of $O(n^{1+o(1)})$ steps where the polynomials are of degree n. The algorithm lends itself easily to several standard optimizations and so we were able to show that by choosing the parameters in the paper appropriately it may be possible to have a feasibly fast implementation that can be used as a component in other algorithms that solve problems such as factorization over finite fields and irreducibility testing. We also analyzed some natural improvements to the algorithm that can significantly improve the practical performance by reducing the constant factors hidden in the big-O notation.

Uncertainty Quantification in Measurements of Electronic Excited-State Absorption
Cesar P Cervantes
Mentor: Mark Stalzer

Nonlinear optical switches and sensors are ideal when implementing materials that have large and fast nonlinear absorption. Furthermore, materials with fast intersystem crossing and long triplet electronic excited state lifetimes are applicable to biomedical applications such as photodynamic therapy for cancerous cells. To characterize nonlinear absorbing materials the coefficients of interest are the electronic excited-state absorption coefficients (σij) and lifetimes (τji). Most of these parameters, however, cannot be measured directly. They require a theoretical model to describe the population dynamics of the electronic energy levels due to a laser pulse as it passes through a sample material. To calculate the values for σij and τji it is imperative that the sample concentration is accurately measured. This is difficult since the sample concentration is typically within 1E-3 and 1E-5 mol/L. The nonlinear absorption measurements were taken by varying the concentrations of the samples (samples were a mixture of Rhodamine 590, a well-known excited-state absorbing laser dye, and Methanol). The Transmission vs. Fluence data at each concentration was then fitted to the theoretical model. To determine the uncertainty in the calculating σij and τji (uncertainty due to uncertainty in concentration) at MATLAB based toolbox is used.

Inexpensive Sensor Networks for Mapping Ground Shaking After Earthquakes
Rishi Chandy
Mentors: K. Mani Chandy and Rob Clayton

The "Did You Feel It?" program developed by the U.S. Geological Survey provides a relatively accurate online earthquake intensity map based on qualitative user reports. To further leverage the power of the community, this project uses inexpensive strong-motion sensors (three-axis accelerometers) connected to personal computers to pinpoint the location of an earthquake and provide early warning to first-responders and those farther away from the epicenter. These small sensors can be used to create a vast community seismic network, which can quickly report large quantities of data to central servers for analysis in the event of an earthquake. Through new robust algorithms resulting from this research, this fault-tolerant system can locate the earthquake epicenter, estimate magnitude, and provide early-warning. With the online interface, users will be able to view this seismic data and analysis in real-time through cell phones or computers in order to better gauge the effect on their communities.

Elastic Deformations
Isaac J. Chao
Mentor: Peter Schroeder

Many modeling tasks require preservation of shape. We define an elastic energy over transformations from a mesh domain to its deformed state which measures its deviation from local isometry by measuring the distance from the differential of the transformation to the special orthogonal group. We argue that an operation minimizing this energy will lead to shape-preserving deformations, and a solver that makes use of gradient and Hessian of the energy will feature fast convergence. This algorithm enables interactive editing, and is practical for modeling applications.

Connecting Medical Devices to Cell Phones
Victor Chu
Mentors: K. Mani Chandy and Julian Bunn

Modern medicine has made significant progress in the past few decades. Unfortunately some of this progress comes at a high cost. Many medical devices are too expensive to be widely available, especially in third world countries. Professor Chanhuei Yang and the Caltech Infospheres group are working on developing inexpensive medical devices linked to cell phones to create portable, widely accessible, first response instruments. This project looks at two devices in particular; the stethoscope and the electrocardiogram. Low cost systems were designed that recorded heart sounds and electrical activity to cell phones, which will be further outfitted with software that can recognize anomalies. This will improve early diagnoses of conditions such as arrhythmias and aortic aneurisms especially in third world countries where access to quality medical equipment is often very limited.

Design and Implementation of Algorithms to Estimate 3D Relative Pose in Mobile Robot Teams
Ryan S Elmquist
Mentors: Stergios Roumeliotis at the Univ. of Minnesota and Mani Chandy

In this project, several algorithms were implemented to solve polynomial systems in floating point representation, based on the eigendecomposition of a so-called multiplication matrix. The methods run using standard double precision and only standard linear algebra packages. The algorithms were implemented with a specific application to compute the 3D relative translation and orientation between two robots, based on known egomotion and six robot-to-robot distance measurements. This has applications in the successful operation of multi-robot systems in GPS-denied or featureless areas. Solving this problem has previously been shown to involve solving a polynomial system of equations that has 40 (generally complex) solutions. Currently available methods to solve these problems either too slow for real-time application, or they require non-standard data types and specialized libraries. This project's methods can find all 40 solutions, trading off speed for accuracy (depending on the method).

Structured Integrators for Computational Magnetohydrodynamics
Evan S. Gawlik
Mentor: Mathieu Desbrun

Lying at the confluence of fluid dynamics and electromagnetism, the field of magnetohydrodynamics (MHD) offers a rich arena for the design of structure-preserving numerical methods for physical simulations. In this study, we derive structured integrators for ideal MHD, which studies the motion of a perfectly conducting incompressible fluid in the presence of a coevolving magnetic field. We begin by outlining the variational formulation of MHD, which treats solutions to the ideal MHD equations as geodesics on a semidirect product between the group of volume-preserving diffeomorphisms of the fluid domain and the space of closed one-forms. We then introduce a structure-preserving spatial discretization of the MHD group setting in a manner that extends the work of previous authors on a discrete exterior calculus-based discretization of incompressible fluid flow. Finally, we perform a temporal discretization of the problem that respects the variational structure of the ideal MHD equations, thereby obtaining a family of variational integrators for MHD. In the process, we derive a general class of variational integrators for semidirect product Lie groups and prove that the algorithms are symplectic and inherit a discrete version of the Kelvin-Noether theorem. We confirm our theoretical results via a numerical implementation of the MHD update equations on a cartesian grid.

Real-Time Earthquake Detection, Using a Distributed Seismic Network
Daniel Obenshain
Mentor: Robert Clayton

Geologists have long sought after early warning for earthquakes as the best way to save lives and prevent property damage. Currently, the seismic network in the Los Angeles area is too slow to provide any early warning. We propose a distributed system using MEMS sensors attached to volunteers computers in homes and schools across the Los Angeles area. This system will have the advantages of a faster response time and a denser network than the existing system.

Cellular Phones for Medical Diagnostics
Aleksandr Palatnik
Mentors: K. Mani Chandy and Julian Bunn

Medical technology has advanced in many ways, but it is still severely lacking in affordability. High costs have made quality healthcare largely unavailable in third-world nations, though cellular phones, which are already common across the globe, offer a potential platform for alternative, low-cost medical technology. The goal of this project is to design software and hardware for a cellular phone to act as a stethoscope and electrocardiogram. Heart sounds can provide information about the heart's pumping ability and the health of various of its valves, while the electrocardiogram can reveal possible heart muscle damage and arrhythmia. By building these technologies on top of existing cellular phone hardware, we aim to create a heart problem early-warning system in third-world countries that is both wide-spread and affordable.

Earthquake Detection and Early Warning via Inexpensive Accelerometers

Daniel E. Rosenberg
Mentors: K. Mani Chandy and Rob Clayton

Seismometers can be bulky and expensive, making it costly and difficult to construct large systems of them. Nowadays, smaller sensors are available for low prices. Three-axis accelerometers are available for as little as about 10 dollars. With such low cost, it would be easy to set up a large network of devices which, although less accurate and reliable than a seismometer, could provide useful information very quickly to a central station. The wide distribution of such sensors could give insight into what regions are more heavily damaged and give invaluable information to rescue workers. The 1994 Northridge quake and the 1989 Loma Prieta quakes had delayed emergency responses due to lack of available data. A widely spread network of smaller sensors would avoid this problem. Our central server can locate and estimate the magnitude of quakes quickly using an algorithm that we developed, tuned via noisy artificial data we created.

An Analysis of the Stump Kernel for Infinite Ensemble Learning

Stephen C. Voinea
Mentor: Yaser S. Abu-Mostafa

Learning from data has become an increasingly important and fruitful area of research with direct applications to finance, biology, computer vision, and speech and handwriting recognition. It is therefore necessary to improve the performance of machine learning techniques over a wide variety of data types. A promising method for achieving this goal can be found in the ensemble learning framework. There is a large body of work supporting this claim, and in particular, there has been recent development into learning with infinite ensembles. A specific instance of infinite ensemble learning can be achieved by applying the Stump Kernel to the Support Vector Machine. An analysis of the classifier produced by using the Stump Kernel is essential in understanding how infinite ensemble learning works. In particular, this analysis should determine how the resulting classifier depends on both the training data and the free parameter associated with the Support Vector Machine.