Third Computational Saturdays - 5/15/10

May 14, 2010

Sponsored by the "Numerical Method for Partial Differential Equation" Seminar and Mathematics Department.

- *Registration: 10:00-10:15*
- *Place: 4-153*

Ryan McLinko

Time: 10:15-10:30

Topological Optimization of Plates for Tensile Strength Using Finite Differencing Techniques

This paper will describe a two dimensional topology optimization routine that is able to determine the lowest mass configuration of a plate given a set of applied loads. The primary figure of merit specified is the material tensile strength. The purpose of this routine is to be a module in a thesis on structural optimization routine for small satellite design, so the topological optimization of trusses is obviously a crucial element of this process. Although it was not possible to achieve the full scope of the project goal, a number of subtleties in topology optimization were found, which will be applicable to the thesis. Any topological optimization routine is a combination of two fundamental elements. First, a PDE integration scheme is necessary. Traditionally, finite elements are used for structural optimization as a standard for structural analysis, but an implicit, second-order finite difference scheme is used in this case in an attempt to better capture the smoothness of the figures of merit. Spectral methods have been attempted, but the discontinuities in boundary conditions and loading conditions make the use of such conditions to be particularly difficult. An optimization scheme is then used to determine the best design that may be used for a given set of constraints. Although there are many options available, a simple sensitivity approach is used for the purposes of this project. Some of the leading alternate schemes are Optimality Criteria methods, Sequential Linear Programming, Method of Moving Asymptotes, Global

Finite Differencing, and (Semi-) Analytical methods. In general, one of these would be the most robust and/or efficient method to use, however the formulation of the structural finite differencing scheme turned out to not work very well with these more complicated optimization schemes. As a result, a simple, several-step, sensitivity analysis optimization scheme was used.

Claudio Di Leo

Time: 10:30-10:45

Eulerian approach to finite-strain elasticity

The use of a method developed recently by K. Kamrin and J.C. Nave, for the simulation of deformable solids is discussed and presented. The method is based on an Eulerian field called the "reference map". The reference map relates the current location of a material point to its initial location. The method is used to simulate large deformations in solid which would otherwise require the finite-element method. I will show a brief introduction of the governing equations of mechanics of solids, followed by a description of the reference map and the discretization used to solve the problem of finite-strain elasticity. Finally, simulations using this novel method for Eularian elasticity are shown.

Adam Lerer

Time: 10:45-11:00

Simulation of 3D Fluid Splashing Using Smoothed Particle Hydrodynamics

Smoothed Particle Hydrodynamics was used to solve the Navier-Stokes equation in 3 dimensions in order to simulate fluid splashing effects such as the Edgerton 'milk crown'. Our model was fully Lagrangian, and different techniques from the literature to model pressure, surface tension, and boundary conditions were compared. The code was optimized and parallelized to allow for simulations of up to 200,000 particles in under 5 seconds per timestep, and rendered in POV-Ray on a computer cluster.

Konuralp Yigit

Time: 11:15-11:30

Path Planning Algorithms for Adaptive Sampling

One important use of Adaptive Sampling is to determine uncertainty and best measurement locations for better Acoustic Sensing Plans. In the near future, there is no doubt that autonomous systems, which utilize Adaptive Sampling, are going to be a crucial part of ocean sampling systems. Developing optimal control algorithms for these systems includes not only the classical problems of underwater robotics, such as obstacle avoidance, path planning for minimum time and energy consumption. It is also a matter of optimum path planning in an uncertain and dynamic ocean environment. In this project, by using Level Set Method, optimized path planning schemes for a swarm AUVs will be developed and solved. Basically, the goal of this project is to find the optimal paths which maximize the accuracy of field estimates for this path.

Bhavya Kishor Daya

Time: 11:30-11:45

Microprocessor Thermal Analysis using the Finite Element Method

The microelectronics industry is pursuing many options to sustain the performance improvement expected every two years. One method for performance improvement is scaling transistor sizes down such that many more transistors can be compacted on chip. The on-chip temperature is a concern because the reliability and performance can be degraded due to hot spots. Thermal modeling of the chip will allow the designer to view the hot spots and adjust the architecture to obtain a reliable chip architecture. In order to meet the performance demands of the current consumer market, the trend towards multicore processors is causing thermal effects to become increasingly important. The method of thermal analysis implementation is evaluated to determine the benefits of the different approaches. The finite element analysis was ultimately chosen and used to perform a case study on a microprocessor, and to evaluate different floorplans for multicore processors. These simple floorplan evaluations are a step towards obtaining a thermally-aware multicore chip platform that can be further evaluated once the detailed layout/floorplan has been established. Heat and hot spots are a challenge in the development of emerging 3D microprocessors. While these challenges are more applicable for high performance applications, designing the 3D chip's floorplan to take heat into account could prevent poor performance in 3D low power processors as well. Tackling thermal analysis for 3D microprocessors and creating thermally-aware 3D chips is the next step in microprocessor thermal analysis and design.

Paul Richardson

Time: 11:45-12:00

A Numerical Solution for the Alluvial-transport Equation

Rivers are often described as exhibiting detachment-limited or transport-limited behavior. In the case of the latter, an alluvial-transport equation is often used to model the evolution of the river profile. The alluvial transport equation is composed of three nonlinear terms and each term exhibits different behavior—nonlinear advection , nonlinear diffusion , and a mixture of nonlinear advection and diffusion. I introduce a new scheme for solving the alluvial transport equation and discuss the stability of each term. Explicit solutions for this equation are extremely sensitive to stability conditions, so a scheme that was partially implicit was used and exhibited much higher stability.

Rohit Pandharkar

Time: 12:00-12:15

Fast L1-Minimization for Sparse Source Detection: Tracking people in a room using single photo diode

We present the algorithmic design and working prototype hardware for tracking people in a room with a single photodiode. Shannon Sampling theorem in signal processing limits the number of measurements required to gain certain resolution. Usually signal capture problems are solved with L2 norm minimization. However, if sparsity prior on the signal is used, L1 minimization enables signal capture with significantly less number of measurements. We exploit the fact that number of people moving in a room is a truly sparse signal; with very few non-zero points, with unknown support .We apply L1 minimization with incoherent projections to solve the problem of recovering locations of people in a room using single active IR LED with dynamic masks.

Peter Rhame Meleney

Time: 13:15-13:30

Modeling Hotspot Mid-Ocean Ridge Interactions: a Numerical Modeling Approach

It has long been thought that hotspot lineaments record the absolute trajectory of tectonic plate motions and that bends in those lineaments represent changes in plate trajectory. However, it has been shown that volcanic hotspots can become pinned at mid-ocean ridges (MOR) because of the extremely thin lithosphere in those locations. The most famous of these is Iceland, which currently erupts at a spreading center along the Mid Atlantic Ridge. Geophysical evidence has recently been used to show that the most pronounced bend in a hotspot lineament, the bend between the Emperor and Hawaiian seamount chains, may be in response to the Hawaiian hotspot having been pinned at a now subducted spreading center that once resided in the Pacific. In order to better understand the properties of hotspot-lithosphere interaction and to better constrain the possibility that the Hawaiian hotspot may have once been pinned at a spreading center, here I present a three-dimensional numerical model in the manner of Ribe and Christensen (1999) which models the interaction of the Hawaiian hotspot with moving lithospheric geometries representing a MOR. The model domain is a rectangular box with a highly viscous fluid moving with an imposed velocity. The viscosity of the fluid is temperature and pressure dependant and the lithosphere is approximated by a very cold and hence rigid layer which thins to non-existence at the center of the MOR.

Kaspar Loeffel

Time: 13:30-13:45

Acoustic wave propagation in spatially heterogeneous solid media

The propagation of acoustic waves has been the subject of scientific discussion for a long time. While a sound theory has been established in the field of mechanics over the past centuries, advancements in computational power have greatly increased the capability of describing acoustic waves. This is due to the fact that analytical solutions are limited to simple, special cases, while numerical solutions are not restricted to these scenarios. In this project, acoustic wave propagation in spatially heterogeneous solids is investigated numerically, demostrating the of the computational treatment of the problem. First, the theoretical framework is briefly discussed. We then examine the numerical implementation in two dimensions, which consists of finite-difference approximations on a staggered grid. Subsequently, verification is performed by choosing a homogeneous solid continuum and comparing the numerical pressure wave speed with the analytical walue, yielding agreement to within two percent, thus verifying the numerical implementation. Finally, the simulation is applied to examine the different propagation time histories of an acoustic wave in a solid continuum depending on the spatial distribution of material properties.

Sidney Tsai

Time: 13:45-14:00

Numerical Simulation of Absorbance Modulation Systems with Thick Absorbance Modulation Layers

Optical point-spread functions (PSFs) refers to the intensity profile in space of a tightly focused optical spot. Because in optical imaging systems, final images are determined by convolutions of objects and the PSF, the size, i.e. the full width half maximum (FWHM), of the PSF determines the resolution of the system. This work presents a method to produce highly localized PSFs by propagating a focused spot at one wavelength and a donut-shaped spot at another wavelength through a photochromic layer called the absorbance modulation layer (AML). By solving a simplified photon transport equation, the time evolution of the AML absorbance and FWHM of the PSF is simulated and optimized for different incident conditions.

Joseph P Yurko

Time: 14:00-14:15

2-D Natural Convection with Combined Heat and Mass Transfer

This study examines natural convection flows with combined buoyancy effects from thermal and concentration gradients. The governing equations are discretized using finite differences and marched forward in time until the solution reaches steady-state. The relative strength between the thermal and concentration gradients can have a significant impact on the flow field and heat transfer rate. Characterizing this impact is important in High Temperature Gas Reactor (HTGR) safety analysis.

Eugeny Sosnovsky

Time: 14:15-14:30

Coupled Neutron Diffusion and Heat Transfer via Bond Graphs

The important physics for reactor simulation include neutron transport and thermal hydraulics, which are inherently strongly coupled. Most current efforts typically only model a single physics where the coupled data is determined externally. This approach is a form of operator splitting, and is poor for high fidelity calculations. One technique for solving this coupling problem is the "bond graph formalism," a state equation-generating architecture first introduced in the 1960s for mechatronic system modeling. Bond graphs have recently been used for pure neutron and thermal diffusion. In this paper, a new optimized bond graph processing code is utilized to model a convectively cooled nuclear fuel rod, and the results compared to an operator splitting approach for the same system.

Gunwoo Noh

Time: 14:30-14:45

Lattice Boltzmann methods for two-phase viscous fluids flow.

A basic Lattice Boltzmann methods for two-phase viscous fluids flows is presented. The Shan-Chen model (Shan, Chen, 1992) is used but some of the part for surface tension are not fully implemented. The dam breaking problem is solved by the implemented code. The numerical results show that the interface between two fluids is broken when the velocity of the fluid is large. Also, it shows the compressible characteristics. The basic concepts of the Lattice Boltzmann methods for fluid flow and some considerations on compressible characteristics and the factors, which affect the surface tension, are discussed.

Marilena Oltmanns

Time: 14:45-15:00

Model for the water exchange in a Greenland fjord

The aim of this project is to model the exchange of waters in a Greenland fjord and on the East Greenland shelf. Recent observations have revealed that the water in Greenland's fjords is surprisingly warm. Previously, it was thought, that water with this temperature is only present on the shelf, while the water in the fjords was thought to be cold and to be of Arctic origin. The new observations raise the question how the warm shelf water can enter the fjord.

It has been suggested that pressure differences along the coast - which result in tilted isopycnals in the coastal water - represent a fast mechanism to exchange water between the shelf and the fjord. Thus, a simplified model using the shallow water equations for a two-layer flow is built that describes how tilted isopycnals can drive the inflow of warm water into the fjord. The results of this model are important for future studies in that they provide estimates for the timescales on which high temperature waters reach and melt Greenland's outlet glaciers.

Brooks Reed

Time: 15:00-15:15

Dynamic System Model Parameter Fitting using Overdetermined Least Squares

For this project, model fitting for dynamical systems using Least Squares optimization methods is investigated. The project motivation is to develop a framework for deriving a system model for an autonomous underwater vehicle, to be used in a model-based feedback controller. For underwater vehicles, model development using physics is very difficult, so an experimental approach is planned. The model will be empirically derived using data from tests where a preset open-loop control action is commanded, and the system output is observed through sensors with some measurement noise. For this exercise, a computer mass-spring-damper system model is used to develop the model-fitting framework. Data is generated using the computer model, with random Gaussian noise added. Overdetermined Least Squares optimization (using the pseudoinverse) is used to estimate the parameters of a discrete system transfer function. The results are compared to the original model, allowing investigation into performance metrics such as estimator bias, and effect of noise parameters on the least squares solution.

Jeremy Alyn Roberts

Time: 15:30-15:45

Direct Solution of the Discrete Ordinates Equations

The purpose of this project is to investigate and implement the discrete ordinates method for one- and two-dimensional multi-group neutron transport, and to solve directly the resulting equations. Historically, the discrete ordinates equations have been solved via the power iteration method (PI). The approach as typically implemented is very memory efficient, but for highly diffusive problems, the PI method is notoriously ineffective. Several techniques to accelerate the PI method have been developed, but they are complicated even for simple geometries. Here, an alternative approach is investigated, which is to solve the discrete ordinates system directly. The general forms of the multi-group discrete ordinates matrices in both one and two dimensions have been derived and implemented in Matlab using its built-in sparse matrix utilities. To solve the systems, both the standard "backslash" for direct elimination and combinations of built-in Krylov solvers (GMRES and BICGSTAB) with ILU preconditioning are studied. The computational expense for these direct approaches is compared to that of the standard PI approach, which has also been implemented in Matlab and verified against a production discrete ordinates code. Preliminary results for one-dimensional, highly diffusive problems suggest that the direct approach (with either elimination or Krylov solvers) is up to an order of magnitude faster than the PI method. However, this efficiency degrades for larger matrix bandwidths, which occurs for higher angular resolution and more energy groups. More complete comparisons in both one and two dimensions and a study of the impact of the ILU preconditioner parameters will be the focus of the full paper.

Mark Massie

Time: 15:45-16:00

Spectral Optimization of Nuclear Fuel Transmutation

Transmutation, or the transformation of one isotope into another through neutron capture, in the nuclear fuel cycle has been extensively studied over the past four decades because of its potential to transform the highly radioactive isotopes in used nuclear fuel (UNF) into more stable nuclei. This transformation would allow for a drastic reduction in the volume of highly radioactive material that needs to be stored in a permanent repository like Yucca Mountain. Although signification research has been conducted on the use of transmutation in the nuclear fuel cycle, most previous studies have used trial and error approaches that only evaluate the recycling effectiveness of existing and next generation reactor designs. This project proposes that instead of simulating current reactor designs and evaluating their performance in transmuting UNF, the problem should be viewed from the opposite direction: define goals related to transmutation and then use optimization to find the best way to reach those goals. In this research, the most important fuel cycle objectives are defined as minimizing decay heat released by UNF while in a permanent repository, minimizing short-term radiotoxicity to allow easier reprocessing of UNF, and minimizing the amount of Pu-239 in UNF to reduce the risk of nuclear weapons proliferation. Although optimization techniques could be applied to almost any design parameter, this project focuses on the energy distribution, or flux spectrum, of incident neutrons. An optimization routine based on simulated annealing is created that determines the optimal flux spectrum for each of the above fuel cycle objectives. Preliminary results show that an optimal flux spectrum for minimizing long term decay heat can reduce the amount of energy released by UNF by almost 50% and can significantly decrease the amount of time for UNF to reach natural radioactivity levels.

Chris Kempes

Time: 16:15-16:30

The environmental and biological regulation of pattern formation in colonies of bacteria

Classic work concerning pattern formation in colonies of cells growing on flat surfaces has focused on the interplay between the response of motile bacteria to chemical gradients, and the production, consumption, diffusion and degradation of those chemicals. In these systems the emergent pattern of bacteria often corresponds to the direction of bacterial motility with bacteria swimming various directions dependent on the corresponding pattern of the chemical field. Here we explore a system where the bacteria form three dimensional structures and the patterns appear as differences in the height of the colony surface. The feedback in our system is between the uptake of oxygen by the colony surface and the motility and behavior of the bacteria living in the colony. Oxygen governs many processes of the bacteria such as growth and metabolic rates as well as the direction of motility, and these processes lend a second layer of feedback mechanisms to our model. Investigations of bacterial structure formation have thus far focused on discrete models which track individual cells at the microscale. Here we address macroscopic features of the entire colony using a continuum approach within a numerical simulation.

Yonatan Tekleab

Time: 16:30-16:45

Capillary Flow of a Red Blood Cell

In the human body, blood is pumped from the lungs to the rest of the body, moving from the large arteries, to smaller arteries, then finally into the smallest capillaries. In the larger arteries, both healthy and sickle erythrocytes are free to flow in groups without altering their natural shapes. However, the internal diameter of a capillary is much smaller, and the erythrocytes must flow single-file as they pass through these narrow passages. This computational model will approximate the blood flow dynamics of the plasma and the red blood cell within the capillary. The model will use the following set of governing fluid dynamics equations: (1) The continuity equation, (2) Navier-Stokes equation, and (3) oxygen-diffusion equation. The flow of the blood within the capillary is characterized by these governing equations and is constrained by the boundary and initial conditions of the flow.

Frank Joseph Centinello

Time: 16:45-17:00

Level Set Propagation with Area Conservation Constraints

A level set function (LSF) has been propagated by advection proportional to mean curvature with the constraint that the area enclosed by the LSF be conserved. This means that a pressure gradient is present in the computation of the velocity. The resulting movement is determined by pressure conservation in regions of low curvature, and is proportional to curvature elsewhere. Numerical stability of this approach is analysed with application to an elliptical LSF.

Abdulaziz AlMuhaidib

Time: 17:00-17:15

Simulating seismic wave propagation in elastic media using arbitrary high order Lax-Wendroff-type scheme

Accurately modeling of elastic wave propagation and simulating the scattering effects caused by irregular topographic features is essential, in particular, for shallow environmental investigations, earthquake site studies, or hydrocarbon exploration. Therefore, I implemented a 2-D finite-difference Lax-Wendroff-type integration scheme that is arbitrary high-order accurate in time and space. The solver combines a 4th-order ADER scheme (Arbitrary high-order accuracy using DERivatives) with a characteristic variable method at the free surface boundary. The ultimate goal was to develop a numerical solver for the elastic wave equation that is stable, accurate, and computationally efficient.

Jessica D. Armour

Time: Private presentaion (Wednesday 5/19/10)

The Effects of Atmospheric Refraction on Large Zenith Angle Data

Atmospheric refraction is the deviation of light or other electromagnetic wave from a straight line as it passes through the atmosphere due to the variation in air density as a function of altitude. When imaging down near the horizon, the effects of atmospheric refraction can cause the resultant images to shimmer, ripple, or be distorted. I will be comparing several methods used to model atmospheric index of refraction as a function of different parameters, using these values to ray trace through the atmosphere, calculating atmospheric refraction effects along a line of sight from an observer to a target. I will then take input images and produce resultant images distorted by refraction effects. This work is broadly applicable to problems encountered by both the space and missile defense communities, as atmospheric refraction can cause skewed metric data dependant on the zenith angle of the observations. Understanding the refraction effects allows us to correct for these effects in the metric data.