Programme & Abstracts

SANUM 2009

The 33rd Annual
South African Symposium on
Numerical and Applied Mathematics

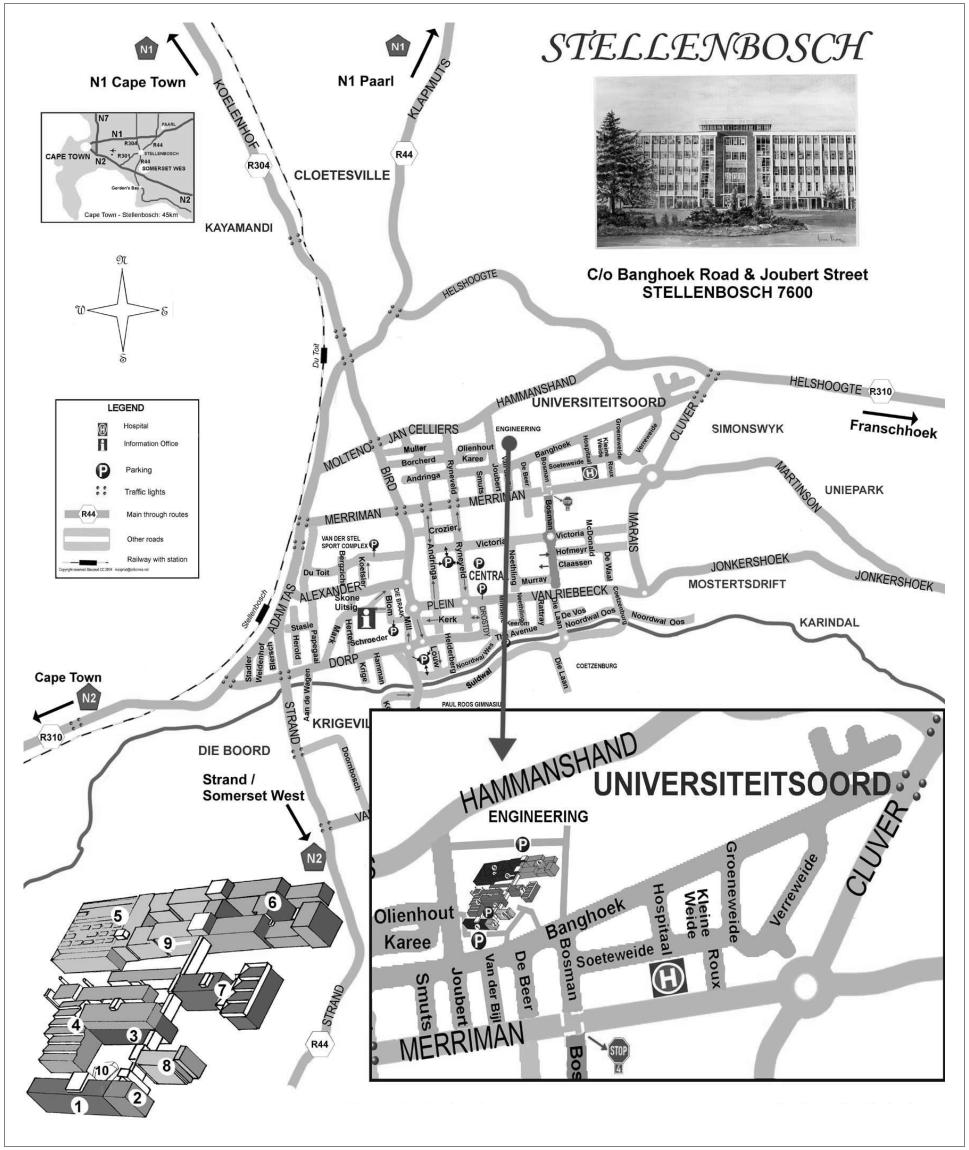
6, 7 and 8 April

Hosted by the
Department of Mathematical Sciences
Stellenbosch University
South Africa

ICIAM

SANUM is sponsored by the International Council for Industrial and Applied Mathematics (ICIAM) under their support scheme for developing countries.

Welcome to SANUM 2009!



Registration takes place on Monday 6 April from 08:15 to 08:50 in the foyer of the general engineering building, located on the corner of Banhoek and Joubert roads (numbered "1" on the map).

Internet Access

Wired network access is available in room A308.

- Automatic proxy configuration:

  http://dip.sun.ac.za/local/proxy.pac

  Login: `sanum`
  Password: `sanum2009`

- Outgoing mail (SMTP) server:

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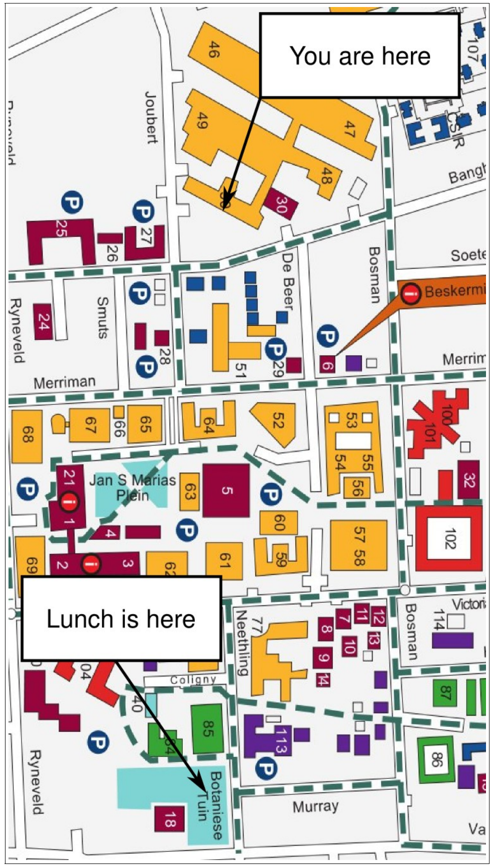

Lunch is served at the Botanical Gardens at 13:00 daily. This is also the venue for the **welcoming reception** on Monday at 18:30, where we meet around light snacks and drinks.

The **conference dinner** is held on the Eaglevlei Wine Estate, 10 minutes' drive outside Stellenbosch. We leave from the parking lot in front of the engineering building at 18:00.

On the cover: Panoramic view of Stellenbosch from Papegaaiberg (Afrikaans for *Parrot Hill*). Photo by Francois Malan.

Time	Monday 6 April			Tuesday 7 April		Wednesday 8 April	
08:15—09:00	Registration						
09:00—09:45	Plenary I ***Maini*** *Mathematical modelling of some aspects of solid tumour growth*			Plenary I ***Peirce*** *Hydraulic Fractures: multiscale phenomena, asymptotic and numerical solutions*		Plenary I ***Fornberg*** *Radial Basis Functions for Solving Partial Differential Equations*	
09:45—10:30	Plenary II ***H.T. Banks*** *Propagation of Uncertainty in Dynamical Systems*			Plenary II ***Ramage*** *Adaptive Grid Methods for Q-Tensor Theory of Liquid Crystals*		Plenary II ***Flyer*** *Applications of Radial Basis Functions in the Geosciences*	
10:30—11:00	Tea						
11:00—11:45	Plenary III ***Kappel*** *Modeling the Impact of BMI on Toxin Concentrations in Hemodialysis Patients*			Plenary III ***Joly*** *Asymptotic Models in Aeroacoustics*		Plenary III ***Milewski*** *Solitary non-integrable wave-packets: stability and dynamics*	
11:45—12:15		**Ackleh** *Deterministic and stochastic juvenile-adult models with application to amphibians*	**Tokman** *Construction and performance of exponential integrators*	**Chabassier** *Energy preserving scheme for a nonlinear system of piano strings*	**Patidar** *On fitted numerical methods for delay differential equations*	**Mason** *Turbulent fluid fracture*	**Banda** *A Multi-level Dynamic Compressor Optimization Approach for Gas Flow Networks*
12:15—12:45		**J. Banks** *Reliability of the use of surrogate species in risk assessment: a population matrix model approach*	**D. Laurie** *Rational approximations to the complex error function*	**Kara** *Symmetry invariance of conservation laws*	**Munyakazi** *On the convergence acceleration techniques for singularly perturbed turning point problems*	**Makinde** *On Thermal Stability of a Non-Newtonian Reactive Flow in a Cylindrical Pipe with Convective cooling*	**Ngnotchouye** *Numerical Implementation of One Dimentional Systems of Conservation Laws on Networks*

13:00—14:15	Lunch (Botanical Gardens)							
14:15—14:45	Special Session on Mathematics in Biology	**Sutton** *Uncertainty and Estimation in Cell Proliferation Modeling*	**Abelman** *Numerical Treatment of First-kind Abel Integral Equations*	Special Session on Vision and Learning	**De Pierro** *The Generalized Attenuated Radon Transform and Its Inversion*	**Bashier** *An efficient numerical method for a delay differential model of two cooperating species*	**Chollom** *Stable Hybrid Methods for the Solution of Stiff Systems of Ordinary Differential Equations*	**Van der Bijl** *Refinement preservation in the bivariate case*
14:45—15:15		**Simons** *The Volcano Effect in Bacterial Chemotaxis*	**Prentice** *Stability regions of RKGL and related methods*		**Fabris-Rotelli** *Clustering by LULU Scale-Space Filtering*	**Ahmed** *On control strategies for co-infection of TB and HIV via mathematical modelling*		
15:15—15:45		**H. Laurie** *A two-patch model for savanna plant/herbivore interaction, with an application to grazing lawns*	**Anguelov** *Structurally Stable Numerical Schemes for Applied Dynamical Models*		**Herbst** *Probabilistic PCA*	**Suleiman** *Mathematical analysis to determine some control strategies for a co-infection model of HIV and malaria*		
15:45—16:15	Tea							
16:15—16:45		**Yusuf** *A mathematical model for controlling the spread of the HIV/AIDS pandemic*	**Van Rensburg** *Solvability of a model for the vibration of a beam with a damping tip body*		**Hoffmann** *Active appearance models fitting*	**Khabir** *Reproducing Kernel Element Method for solving an option pricing models*		
16:45—17:15		**Farbod** *Moment Estimation for Some Discrete Distributions Generated by Stable Laws*	**Van der Merwe** *Numerical simulation of the vibration of a Timoshenko beam with boundary damping*		**Colville** *Introduction to the Centre for High Performance Computing*	**Sidahmed** *Use of mesh free methods to price an American option*		
18:30	Welcoming Reception (Botanical Gardens)			Conference Dinner (Eaglevlei Wine Estate)				

Monday 06 April

MATHEMATICAL MODELLING OF SOME ASPECTS OF SOLID TUMOUR GROWTH

Prof. Philip Maini (University of Oxford)

We use a number of mathematical modelling techniques (ODEs, PDEs, hybrid cellular automata and other discrete cell-based approaches) to address a number of problems in cancer biology. Applications will include escape from homeostatis in colorectal cancer, somatic evolution in breast cancer and multiscale modelling in vascular tumour growth.

PROPAGATION OF UNCERTAINTY IN DYNAMICAL SYSTEMS

Prof. H.T. Banks (N.C. State University)

After discussing the shortcomings of a crypto-deterministic formulation, we compare two other approaches for inclusion of uncertainty/variability in modeling growth in size-structured population models. One entails imposing a probabilistic structure on growth rates in the population that leads to random differential equations while the other involves formulating growth as a stochastic Markov diffusion process, resulting in forward Kolmogorov or Fokker-Planck equations. We present a theoretical analysis that allows one to include comparable levels of uncertainty in the two distinct formulations in making comparisons of the two approaches. Computational aspects of the approaches are also discussed.

MODELING THE IMPACT OF BMI ON TOXIN CONCENTRATIONS IN HEMODIALYSIS PATIENTS

Prof. Franz Kappel (University of Graz)

Recent studies have shown that dialysis patients with a higher BMI on the long run do better than patients with a low BMI provided they undergo the same treatment. One explanation is that a larger volume of adipose tissue has a buffering function, so that the toxin concentration in extracellular fluid is lower during the interdialytic periods. We present a compartment model which is capable to model this effect. Furthermore, we discuss problems associated with parameter estimation for this model.

DETERMINISTIC AND STOCHASTIC JUVENILE-ADULT MODELS WITH APPLICATION TO AMPHIBIANS

Prof. Azmy Ackleh (University of Louisiana at Lafayette)

We develop a deterministic juvenile-adult model where juveniles are structured by age and adults are structured by size. This model is described by a system of nonlinear first order hyperbolic equations. Existence-uniqueness of weak solutions is discussed and convergence of a finite difference approximation to the unique weak solutions is established. This finite difference approximation is then used to compare the model output, via a least-squares approach, to statistical population estimates of green tree frogs, which are obtained from capture-mark-recapture field data. To test the effect of demographic stochasticity, we develop stochastic versions of the deterministic model which account for randomness in birth death, and age/size changes and present numerical results for the dynamics of these stochastic models.

RELIABILITY OF THE USE OF SURROGATE SPECIES IN RISK ASSESSMENT: A POPULATION MATRIX MODEL APPROACH

Dr John E. Banks (University of Washington)

The use of surrogate species is an important tool for predicting the effects of management decisions or the establishment of protective measures for endangered/threatened species. However, relying on a handful of common species as a means of predicting the fate of a wide suite of endangered species is potentially fraught with problems, especially when static metrics such as LD/LC 50 are used. Using a matrix model, we derive a closed-form mathematical expression aimed at determining when surrogate species population outcomes will reliably predict outcomes of target (listed) species. In particular, we develop an inequality that indicates how dissimilar life history traits (survival & fecundity) of the surrogate and listed species may be before the surrogate species outcomes indicate a positive population growth, whereas the listed species is driven to extinction. We compare our derived criterion to several fish surrogate species and their target salmonid species, and discuss more general applications of our findings.

UNCERTAINTY AND ESTIMATION IN CELL PROLIFERATION MODELING

Dr Karyn Sutton (North Carolina State University)

Changes in cell proliferation are indicative of disease progression or the worsening of a medical conditions in many instances, with cancer being an obvious example. The standardization of fluorescent labeling of cells as measured by flow cytometry has allowed for potential in quantification of proliferation dynamics. We discuss a model of cell proliferation dynamics where the fluorescent label is a structure variable. We outline areas in which uncertainty should be explicitly incorporated in the model and discuss the estimation of parameters via inverse problem methodology.

THE VOLCANO EFFECT IN BACTERIAL CHEMOTAXIS

Julie Simons (University of Wisconsin, Madison)

A classic problem in biology is to model organisms at the population level, circumventing the complexity of describing each individual's behavior. Population-level models are either written outright by postulating reasonable macroscopic behavior (often as flux laws with sources/sinks), or by describing the phenomena on an organism scale and deducing these laws. In bacterial chemotaxis–the description of biased motion of bacteria towards optimal environments–the simplest macroscopic models are written with Keller-Segel (KS) type equations. Such models are able to capture many aspects of the behavior of a population, and only recently have been deduced from a reasonable organism-level description of behavior. There are, however, situations where the bacterial behavior is not captured by KS models: we focus in particular on experimental and computational results which demonstrate that under certain conditions bacteria will aggregate some distance away from a peak in its attractant. In this work, we propose a microscopic explanation for this phenomenon and present population- level models that go beyond the KS models, derived from organism-level behavior.

A TWO-PATCH MODEL FOR SAVANNA PLANT/HERBIVORE INTERACTION, WITH AN APPLICATION TO GRAZING LAWNS

Henri Laurie (University of Cape Town)

We formulate a two-patch version of Norman Owen-Smith's GMM model for biomass density of a idealised herbivore feeding on a idealised resource in a seasonal environment. The formulation is a straightforward extension: GMM on each patch and migration between patches. Patch areas are explicit. We assume that migration may be influenced by the amount of vegetation in the local patch, but is independent of other factors. The seasonality introduces time-dependence in the parameters, so that the resulting equations are not autonomous. We briefly review some analytical results for the analogical autonomous system and display some computational results for the full system. We then apply the model to a system consisting of two types of vegetation, one with low carrying capacity but fast growth and higher nutrition which we claim mimics the role of grazing lawns. The results appear to indicate that grazing lawns are disadvantageous to animal growth under GMM.

A MATHEMATICAL MODEL FOR CONTROLLING THE SPREAD OF THE HIV/AIDS PANDEMIC

Tajudeen Yusuf (University of the Western Cape)

Authors: T.T.Yusuf and F.Benyah We present a deterministic model for the spread and control of HIV/AIDS infection. The model is used to examine various combinations of control efforts in reducing the spread of the pandemic.

MOMENT ESTIMATION FOR SOME DISCRETE DISTRIBUTIONS GENERATED BY STABLE LAWS

Davood Farbod (Yerevan State University)

Davood Farbod Yerevan State University In bioinformatics there are well-known discrete distributions that have properties like Stable Laws. We are constructing in such discrete distributions. In the present article an algorithm which is based on Newton-Raphson method to moment estimator of the index α for some truncated discrete distributions generated by maximally skewed Stable Laws is proposed. Numerical examples are studied and support our theory. Taking into account that the logarithm transformation of such discrete random variable has finite moments of any order, we consider moment estimation for logarithm of it. Key words: Index α; Moment Estimate; Newton-Raphson Method; Stable Laws.

CONSTRUCTION AND PERFORMANCE OF EXPONENTIAL INTEGRATORS

Prof. Mayya Tokman (University of California, Merced)

Exponential integrators offer an alternative way to integrate nonlinear systems of ODEs compared to explicit and implicit methods. A particularly advantageous characteristic of exponential schemes is their efficiency in integrating large stiff systems. While first exponential schemes were introduced in early 1960's they haven't attained wide popularity since they were considered prohibitively expensive. A proposal to combine Krylov projection algorithm and exponential integration alleviated this computational constraint

and was followed by a resurgence of interest in these methods. In this talk we will describe what are the building blocks in construction of an efficient exponential integrator and provide an overview of research efforts in development of competitive schemes of this type. We will discuss such important aspects of these methods as optimization of computational complexity per integration step, derivation of order conditions using B-series and development of adaptive integration strategies. Performance of exponential integrators will be evaluated using a suite of test problems and comparing them with standard methods.

RATIONAL APPROXIMATIONS TO THE COMPLEX ERROR FUNCTION

Prof. Dirk Laurie (Stellenbosch University)

We start from Weideman's 1994 paper on evaluation of the complex error function (also known as the Faddeeva function) by a formula valid in all of the upper half-plane. That formula can be viewed as an $(n-1, n)$ rational approximation in which the denominator has a single pole of appropriate multiplicity, and can be derived by transforming a certain auxiliary function to the upper half-plane to the unit disk by a Möbius transformation that maps the pole in question to infinity, followed by Taylor expansion around the origin. Instead of Taylor expansion, we use near-best rational approximation on the unit circle to obtain the same accuracy with n reduced by a factor of more than two.

NUMERICAL TREATMENT OF FIRST-KIND ABEL INTEGRAL EQUATIONS

Prof. Shirley Abelman (University of the Witwatersrand)

A rational basis set is constructed using [1; 1] rational interpolation. The basis is used in a product integration method for solving first-kind Abel integral equations.

STABILITY REGIONS OF RKGL AND RELATED METHODS

Dr Justin Prentice (University of Johannesburg)

We describe the RKrGLm method for solving ODEs, and we show the stability regions of RK5GL3, which is a fully explicit realization of RKrGLm. We consider implicit forms of the method in which the GL component is replaced with closed Newton-Cotes (NC) quadrature, and we suggest that if the underlying Runge-Kutta (RK) method is explicit, the method will likely never be A-stable. If RK is implicit, however, the possibility of A-stability does exist. We show that the method IRK3NC4 seems to be $A(\alpha)$-stable, with $\alpha \approx 89°$.

STRUCTURALLY STABLE NUMERICAL SCHEMES FOR APPLIED DYNAMICAL MODELS

Prof. Roumen Anguelov (University of Pretoria)

We consider the construction of reliable numerical discretizations of continuous dynamical systems arising as models of different natural phenomena, with a focus on schemes which correctly replicate the properties of the original dynamical systems. The work is based on the new concept of topological dynamic consistency, which describes in precise terms the alignment of the properties of the discrete dynamical system and the approximated continuous dynamical system. This development is based on the important observation that the "dynamics" of a dynamical system, e.g. fixed points, periodic orbits, non-wandering set, and the way these final states are approached, are topological properties. Consequently, we consider the similarity of a continuous dynamical system with the associated numerical methods, viewed as discrete dynamical systems, in the sense of topological equivalence between the corresponding evolution operators. In this conceptual setting the structural stability of the evolution operators of the original system and its discretization play an important role. We recall that the notion of structural stability is defined with respect to certain functional space, typically the space of all smooth maps. For models in practical applications this space is often not applicable and we show how one can design an appropriate space V for a specific model, so that the evolution operator is V stable. Our approach is to construct a discretization such that the evolution operator of the respective discrete dynamical system is in V and is also V structurally stable. Then the topological dynamic consistency of the schemes follows in a natural way. In the construction of the schemes we use Mickens' non-standard finite difference method. A numerical procedure for the classic endemic model for the spread of disease is derived by using nonlocal approximation of the nonlinear term. The topological dynamic consistency of the scheme is obtained via the structural stability of the evolution operators with respect to a suitably defined function space V.

SOLVABILITY OF A MODEL FOR THE VIBRATION OF A BEAM WITH A DAMPING TIP BODY

Prof. Nic van Rensburg (University of Pretoria)

We consider a model for the vibration of a beam with a damping tip body in a recent article (2002). We derive a variational form for the motion of the beam and use it to prove that the model problem has a unique weak solution. The proofs are based on existence results for a general linear vibration model problem published in 2002. It is important to realize that the existence of solutions for problems involving partial differential equations is not a black or white issue; there exists an hierarchy of possible solutions. We present elementary examples to illustrate this fact.

NUMERICAL SIMULATION OF THE VIBRATION OF A TIMOSHENKO BEAM WITH BOUNDARY DAMPING

Dr Alna van der Merwe (CPUT)

The Timoshenko beam model consists of two partial differential equations; one for the deflection of the beam and another for the angle due to rotation of a cross section. The effect of boundary damping on the vibration of a Timoshenko beam has been studied previously by solving the associated eigenvalue problem. For a problem of this nature, spectral analysis may not be sufficient to predict the dynamic behaviour of the beam. We present examples of numerical simulations of the transverse vibration of a Timoshenko beam with boundary damping. In particular, these examples illustrate how the effect of the boundary damping depends in a significant way on the initial state of the beam.

Tuesday 07 April

HYDRAULIC FRACTURES: MULTISCALE PHENOMENA, ASYMPTOTIC AND NUMERICAL SOLUTIONS

Prof. Anthony Peirce (University of British Columbia)

Hydraulic fractures (HF) are a class of tensile fractures that propagate in brittle materials by the injection of a pressurized viscous fluid. In this talk I introduce models of HF and provide examples of natural HF and situations in which HF are used in industrial problems. Natural examples of HF include the formation of dykes by the intrusion of pressurized magma from deep chambers. They are also used in a multiplicity of engineering applications, including: the deliberate formation of fracture surfaces in granite quarries; waste disposal; remediation of contaminated soils; cave inducement in mining; and fracturing of hydrocarbon bearing rocks in order to enhance production of oil and gas wells. Novel and emerging applications of this technology include CO2 sequestration and the enhancement of fracture networks to capture geothermal energy. I describe the governing equations in 1-2D as well as 2-3D models of HF, which involve a coupled system of degenerate nonlinear integro-partial differential equations as well as a free boundary. I demonstrate, via re-scaling the 1-2D model, how the active physical processes manifest themselves in the HF model and show how a balance between the dominant physical processes leads to special solutions. I discuss the challenges for efficient and robust numerical modeling of the 2-3D HF problem including: the rapid construction of Green's functions for cracks in layered elastic media, robust iterative techniques to solve the extremely stiff coupled equations, and a novel Implicit Level Set Algorithm (ILSA) to resolve the free boundary problem. The efficacy of these techniques is demonstrated with numerical results.

ADAPTIVE GRID METHODS FOR Q-TENSOR THEORY OF LIQUID CRYSTALS

Dr Alison Ramage (University of Strathclyde)

In addition to the defect core structure, the dynamics of defect movement is also a crucial issue for liquid crystal cells. Previous numerical simulations of such effects have mostly involved using standard finite difference or finite element techniques on uniform grids, and have often been based on using director theory rather than the Q-tensor approach proposed here. However, the presence in the physical problem of characteristic lengths with large scale differences (the size of the defect is very small compared to that of the cell) suggests that more sophisticated numerical modelling techniques could be used to great effect. One obvious approach is to use an adaptive grid technique, ensuring that there is no waste of computational effort in areas where there is no need for a fine grid. Adaptive grid methods have been successfully used to solve PDEs in many branches of computational mathematics such as computational fluid dynamics, mathematical biology, semiconductor modelling and aerospace engineering. In this talk we will present an introductory study of the use of adaptive grid methods for solving PDE problems in Q-tensor theory of liquid crystals. This work is in collaboration with Dr Christopher J. Newton of Hewlett-Packard Laboratories in Bristol, UK.

ASYMPTOTIC MODELS IN AEROACOUSTICS

Dr Patrick Joly (INRIA)

In many applications in aeroacoustics, in particular in aeronautics, it is important to simulate the interactions of acoustic waves with boundaries (walls, wings,...). Moreover, boundary layers of very small width are present close to the boundaries. The question of a satisfactory treatment of boundaries in aeroacoustics remains essentially open. In this work, we study acoustic wave propagation in a thin duct, in the presence of a laminated flow, a problem which can be seen as a first step towards the treatment of such boundary layers. We use an asymptotic analysis when the width of the duct is small with respect to the wavelength, which amounts to a low frequency analysis, assuming that the Mach profile of the flow is obtained by a scaling of a reference profile M(y). We establish a limit model and study its well-posedness. On the one hand, we exhibit some profiles for which the model is strongly ill-posed and obtain, as a by-product, new instability results for compressible linearized Euler equations. On the other hand, we establish sufficient conditions on M(y) for the model to be well posed : the weak well-posedness of the Cauchy problem is obtained via a quasi-explicit representation of the solution, using the Fourier-Laplace transform in space-time. Numerical illustrations will be presented. Finally, we shall show how these results can be used to construct effective boundary conditions for boundary layers.

ENERGY PRESERVING SCHEME FOR A NONLINEAR SYSTEM OF PIANO STRINGS

Juliette Chabassier (INRIA)

The linear wave equation does not describe the complexity of the piano strings vibration enough for physics based sound synthesis. The nonlinear coupling between transversal and longitudinal modes has to be taken into account, as does the "geometrically exact" model. This system of equations can be classified among a general energy preserving class of systems. We present an implicit, centered, second order accurate, numerical scheme that preserves a discrete energy, leading to unconditional stability of the numerical scheme. The complete model takes into account the bridge coupling the strings, and the hammer non linear attack on the strings.

SYMMETRY INVARIANCE OF CONSERVATION LAWS

Prof. Abdul Hamid Kara (University of the Witwatersrand)

The use of symmetry properties of a given system of partial differential equations to generate new conservation laws from known conservation laws and the concept of basis of conservation laws has been investigated. Furthermore, it has been shown that one can construct new conservation laws for a given system of differential equations by the action of any symmetry generators on the known conservation laws of the given system of differential equations without having to transform the symmetry generators to canonical symmetry generators. The generated conservation laws are non-trivial if the given system of differential equations are derivable from a variational principle. The role of 'multipliers' has been thoroughly investigated - particularly, in the construction of new /higher-order conservation laws. There is a determining system for finding ALL multipliers (and hence all conservation laws) for any given PDE system. The determining system consists of the adjoint of the symmetry determining equation plus certain extra determining equations (called adjoint-invariance conditions) formulated entirely on the solution space. This comes from applying the Euler operator to the multiplier expression and then splitting the resulting equations.

ON FITTED NUMERICAL METHODS FOR DELAY DIFFERENTIAL EQUATIONS

Prof. Kailash C. Patidar (University of the Western Cape)

Several numerical methods have been developed in the past to solve complex differential models. However, it is difficult to extend some or most of these methods to solve the delay differential equations (DDEs). In this talk, we will consider some DDEs and describe construction and analysis of some fitted numerical methods for such problems.

ON THE CONVERGENCE ACCELERATION TECHNIQUES FOR SINGULARLY PERTURBED TURNING POINT PROBLEMS

Justin B. Munyakazi (University of the Western Cape)

Convergence acceleration techniques have been discussed a lot for singularly perturbed problems without turning point problems. However, very few works are found the turning point problems. In this talk, we will consider a singularly perturbed turning point problem and firstly discuss construction, analysis and implementation of some novel numerical methods. Then we discuss about how we accelerate the convergence of these methods.

THE GENERALIZED ATTENUATED RADON TRANSFORM AND ITS INVERSION: APPLICATION IN X-RAY FLUORESCENCE TOMOGRAPHY

Prof. Alvaro De Pierro (University of Campinas)

X-ray Computed Tomography (CT) is one of the most important imaging techniques for medical diagnosis. Mathematically, it consists of inverting the well known Radon Transform, that is nothing but the set of line integrals of the function we want to reconstruct. In other applications, like Single Photon Emission Computed Tomography (SPECT), where the function to be reconstructed is photon emission inside the body, an attenuation factor appears under the integral, giving rise to a more difficult inversion. In X-ray Fluorescence Computed Tomography (XFCT), the emission is produced by the excitation by an outer source of intense X-rays. This generates a still more complicated operator containing the attenuation of the X-rays and of the emitted fluorescence as well. In this work, we describe the analytic and the iterative inversion of the XFCT Transform. We deduce new mathematical formulas using ideas from recent transforms that appear in the solution of Boundary Value Problems. We also present experimental results with simulated as well as synchrotron generated real data.

CLUSTERING BY LULU SCALE-SPACE FILTERING

Inger Fabris-Rotelli (University of Pretoria)

Multidimensional LULU operator theory has been derived and the application of it in Image Processing investigated - specifically, their application to clustering of images and object detection. Their advantage over standard clustering is due to the knowledge of the image structures at all scales, hence the Scale-Space theory, as well as the intrinsic shape properties of objects at all scales which is all available through the decomposition of the image by the LULU operators, the Discrete Pulse Transform.

PROBABILISTIC PCA

Prof. Ben Herbst (Stellenbosch University)

I'll give an overview of probabilistic PCA, and illustrate it with examples.

ACTIVE APPEARANCE MODELS FITTING

McElory Hoffmann (University of Stellenbosch)

Active appearance models (AAMs) (Cootes et al., 1998; Edwards et al., 1998) are deformable template models using shape and texture (grayscale or colour information) to segment objects of interest from an image. They are a generalisation of active shape models (ASMs) (Cootes et al., 1995) that only use shape information. In this talk, I shall discuss fitting methods of AAMs with an emphasis on non- linear techniques. References Cootes, T. F., Edwards, G. J., Taylor, C. J., 1998. Active appearance models. In: European Conference on Computer Vision. Vol. 2. pp. 484–498. Edwards, G. J., Taylor, C. J., Cootes, T. F., 1998. Interpreting face images using active appearance models. In: FG '98: Proceedings of the 3rd. International Conference on Face & Gesture Recognition. IEEE Computer Society, Washington, DC, USA, pp. 300–305. Cootes, T., Taylor, C., Cooper, D., Graham, J., 1995. Active Shape Models-Their Training and Application. Computer Vision and Image Understanding 61 (1), 38–59.

INTRODUCTION TO THE CENTRE FOR HIGH PERFORMANCE COMPUTING

Kevin Colville (CHPC)

The Centre for High Performance Computing (CHPC) is a multi- disciplinary national resource providing high performance computer resources for research and development. These resources include a 640 processor distributed cluster with 1.25 TB of RAM, a 32 processor shared memory machine, and 91 TB in a high speed storage array network (SAN). The CHPC is also hosts the 4096 processor IBM Blue Gene/P of the IBM Blue Gene for Africa project. The CHPC aims to enhance significant research, address grand challenges, and grow computational research into a viable mode alongside experiment and theory across all academic disciplines. The CHPC's commitment to the advancement of science through the facilitation of world-class science is apparent in its promotion and facilitation of the use of computational technologies and research techniques; fostering of innovation through effective partnerships; and training of a new generation of computationally-skilled researchers in areas underpinned by high-end computing. The Centre for High Performance Computing (CHPC) is an initiative of the Department of Science and Technology and is managed by the Meraka Institute of the CSIR.

AN EFFICIENT NUMERICAL METHOD FOR A DELAY DIFFERENTIAL MODEL OF TWO COOPERATING SPECIES

Eihab B. M. Bashier (University of the Western Cape)

Authors: E.B.M. Bashier and K.C. Patidar Abstract: We consider a system of two coupled partial delay differential equations (PDDEs) describing the dynamics of two cooperative species. The original system is reduced to a system of ordinary delay differential equations (DDEs) obtained by applying the method of lines. Then we construct a fitted operator finite difference method (FOFDM) to solve this resulting system. The model considered in this paper is very sensitive to small changes in the parameters associated in with the model. Depending on the values of these parameters, the solution can be stable, periodic and/or aperiodic. Such behavior of the solution is exploited via the proposed FOFDM. This FOFDM is analyzed for convergence and it is seen that this method is unconditionally stable and has the accuracy of $\mathcal{O}(k + h^2)$, where k and h denote time and space step-sizes, respectively. Some numerical results confirming theoretical observations are also presented. These results are comparable with those obtained in the literature.

ON CONTROL STRATEGIES FOR CO-INFECTION OF TB AND HIV VIA MATHEMATICAL MODELLING

Hasim A. O. Ahmed (University of the Western Cape)

In this talk we consider a co-infection model of TB and HIV. By going through the sub-cases, we will discuss the derivation of the optimal system. Then we discuss appropriate numerical methods to solve the resulting system.

MATHEMATICAL ANALYSIS TO DETERMINE SOME CONTROL STRATEGIES FOR A CO-INFECTION MODEL OF HIV AND MALARIA

Sara M. A. Suleiman (University of the Western Cape)

In this talk, we will discuss a mathematical model of HIV and Malaria co-infection. Through some qualitative analysis, the derivation of an optimal control model will then be discussed.

REPRODUCING KERNEL ELEMENT METHOD FOR SOLVING AN OPTION PRICING MODELS

Mohmed H. M. Khabir (University of the Western Cape)

We will review some option pricing models using the differential equation approach and then we will discuss the application of the Reproducing Kernel Element Method to solve a differential model to price the American put options.

USE OF MESH FREE METHODS TO PRICE AN AMERICAN OPTION

Abdelmgid O. M. Sidahmed (University of the Western Cape)

Mesh free methods are used a lot to solve the partial differential equation models in the past. In this talk, we will describe how to use these approaches to price an American option using the Black-Scholes framework.

Wednesday 08 April

RADIAL BASIS FUNCTIONS FOR SOLVING PARTIAL DIFFERENTIAL EQUATIONS

Prof. Bengt Fornberg (University of Colorado)

For the task of solving PDEs, finite difference (FD) methods are particularly easy to implement. Finite element (FE) methods are more flexible geometrically, but tend to be difficult to make very accurate. Pseudospectral (PS) methods can be seen as a limit of FD methods if one keeps on increasing their order of accuracy. They are extremely effective in many situations, but this strength comes at the price of very severe geometric restrictions. A more standard introduction to PS methods (rather than via FD methods of increasing orders of accuracy) is in terms of expansions in orthogonal functions (such as Fourier, Chebyshev, etc.). Radial basis functions (RBFs) were first proposed around 1970 as a tool for interpolating scattered data. Since then, both our knowledge about RBFs and their range of applications have grown tremendously. After introducing them, we will focus on their use for solving a wide range of PDEs (which includes PDEs in the geosciences, as Dr. Natasha Flyer will describe in a following presentation). In this context of solving PDEs, we can see the RBF approach as a major generalization of PS methods, abandoning the orthogonality of the basis functions and in return obtaining vastly improved simplicity and flexibility. Spectral accuracy becomes now easily available also when using completely unstructured meshes, permitting local node refinements in critical areas. A very counterintuitive parameter range (making all the RBFs very flat) turns out to be of special interest. Computational cost and numerical stability were initially seen as potential difficulties, but major progress have recently been made also in these areas.

APPLICATIONS OF RADIAL BASIS FUNCTIONS IN THE GEOSCIENCES

Dr Natasha Flyer (NCAR)

Current community models in the geosciences employ a variety of numerical methods from finite-difference, finite-volume, finite- or spectral-elements, to pseudospectral methods. All have specialized strengths but also serious weaknesses. The first three methods are generally considered low-order and can involve high algorithmic complexity (as in triangular elements or unstructured meshes). Global spectral methods do not practically allow for local mesh refinement and often involve cumbersome algebra, especially in spherical geometry. Radial basis functions have the advantage of being spectrally accurate for arbitrary node layouts in multi-dimensions with extreme algorithmic simplicity, and naturally permit local node refinement. We will show test examples ranging from vortex roll-ups, modeling idealized cyclogenesis, to 2-D unsteady nonlinear flows posed by the shallow water equations to 3-D mantle convection in the earth's interior. Their performance will be evaluated based on numerical accuracy, stability and computational performance.

SOLITARY NON-INTEGRABLE WAVE-PACKETS: STABILITY AND DYNAMICS

Prof. Paul Milewski (University of Wisconsin)

Often, the dynamics of slowly modulated wavepackets are studied with envelope type equations such as the Nonlinear Schrödinger Equation and its relatives. In some situations, however, there can be serious issues with such a modelling assumption, and we discuss an alternative: a "primitive" equation (governing the waves themselves not their envelope) which appears to be a more realistic model to the stability and dynamics of such waves.

TURBULENT FLUID FRACTURE

Prof. David Mason (University of the Witwatersrand)

The propagation of a two-dimensional turbulent fluid fracture in impermeable rock is considered. The fluid flow is turbulent if the Reynolds number is sufficiently high.The PKN approximation is made in which the mean fluid pressure in the fracture is proportional to the fracture half-width.The partial differential equation for the half- width has the form of of a nonlinear diffusion equation with a parameter which takes values depending on whether the flow is laminar or turbulent. A similarity solution is derived for a pre-existing one- sided turbulent fluid fracture by considering a linear combination of the Lie point symmetries of the nonlinear diffusion equation. The effect of turbulence on the propagation of the fracture is investigated.

ON THERMAL STABILITY OF A NON-NEWTONIAN REACTIVE FLOW IN A CYLINDRICAL PIPE WITH CONVECTIVE COOLING

Prof. Oluwole Daniel Makinde (Cape-Peninsula University of Technology)

A large class of non-Newtonian fluids used in industries is chemically reactive (e.g. coal slurries, polymer solutions or melts, drilling mud, hydrocarbon oils, grease) when subjected to external heating and high shear. This may lead to a high temperature being generated within the fluid. Hence, the study of heat transfer and thermal criticality of reactive non-Newtonian fluids is extremely important in order to ensure safety of life and properties during handling and processing of such fluids. In this paper, the effect of convective cooling on a reactive third-grade fluid flowing steadily through a cylindrical pipe is investigated. It is assumed that the system exchange heat with the ambient following Newton's cooling law and the reaction is exothermic under Arrhenius kinetics, neglecting the consumption of the material. The simplified governing nonlinear equations of momentum and energy are obtained and solved using a special type of the Hermite–Padé approximation technique. Important properties of the overall flow structure including velocity field, temperature field, bifurcations, and thermal criticality conditions are obtained and discussed quantitatively. Keywords: Cylindrical pipe; Third-grade fluid; Arrhenius kinetics; Thermal criticality, Hermite–Padé approximants,Convective cooling. Reference: [1] Y. Tourigny, P.G. Drazin, The asymptotic behaviour of algebraic approximants, Proc. Roy. Soc. Lond. A456 (2000) 1117–1137. [2] O. D. Makinde. Analysis of non- Newtonian reactive flow in a cylindrical pipe. Journal of Applied Mechanics, Vol. 76, 034502 (1-5), 2009. [3] O. D. Makinde. On the Chebyshev collocation spectral approach to stability of fluid flow in a porous medium. Int. J. Numer. Meth. Fluids 59:791–799, 2009. [4] O. D. Makinde. Thermal criticality for a reactive gravity driven thin film flow of a third-grade fluid with adiabatic free surface down an inclined plane. Appl. Math. Mech. -Engl. Ed. Vol 30(3), 373-380, 2009. [5] O. D. Makinde. Thermal stability of a reactive viscous flow through a porous-saturated channel with convective boundary conditions. Applied Thermal Engineering, Vol. 29, 1773–1777, 2009.

STABLE HYBRID METHODS FOR THE SOLUTION OF STIFF SYSTEMS OF ORDINARY DIFFERENTIAL EQUATIONS

Dr Joshua Chollom (University of Jos)

The construction of A stable Block Hybrid Adams Moulton Formulae (BH) for the solution of stiff systems of Ordinary Differential Equations of order k+2 is discussed. These methods are constructed for k=2,3 by incorporating one off grid point for each step number.The methods are self-starting and have shown to posses attractive stability and convergence properties. A numerical experiment carried to investigate the accuracy of the method reveals its efficiency when compared with the state of the art stiff Mat lab ODE solver (ode 23).

A MULTI-LEVEL DYNAMIC COMPRESSOR OPTIMIZATION APPROACH FOR GAS FLOW NETWORKS

Prof. Mapundi Banda (University of the Witwatersrand)

We present an efficient approach for dynamic compressor optimisation in gas networks based on space-mapping. For the fine space a nonlinear isothermal gas flow model is applied while as for the coarse space an algebraic model is employed. To solve an algebraic model is cheaper than solving a nonlinear model. It is desirable though to bring as much nonlinear effects into the optimisation as possible. The mathematical formulation and algorithmic aspects of such a space- mapping approach will be presented. Computational results and comparison between different approaches is presented. The results demonstrate that such a multi-level approach provides accurate results efficiently.

NUMERICAL IMPLEMENTATION OF ONE DIMENTIONAL SYSTEMS OF CONSERVATION LAWS ON NETWORKS

J. Medard T. Ngnotchouye (University of KwaZulu-Natal)

In this talk we discuss some techniques for the implementation of a numerical approach for approximating a system of conservation laws in a network of tubes, rivers, or channels. The dynamic of the vertex is of major interest. The key result here is on the coupling of different models for each arc at the junction. After prescribing a generally nonlinear algebraic system of coupling conditions at the junction, the theory of Lax Riemann Solvers is used to render the system solvable. The implementation combines a solver for the nonlinear coupling conditions and a non-oscillatory high-order method for the solution of the flow equations.

REFINEMENT PRESERVATION IN THE BIVARIATE CASE

Rinske van der Bijl (Stellenbosch University)

We show how to generate refinable functions from previous ones in such a way that refinability is preserved. As a foremost example of a refinable function, we shall make use of various box splines throughout. For the case where the dilation matrix is twice the identity matrix, we obtain results for arbitrary direction matrices, whereas restricting our attention to diagonal dilation matrices in general. Not only is such refinement preservation useful for the theory it opens up, but it moreover leads to the enhancement of the smoothness class of the refinable function.

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