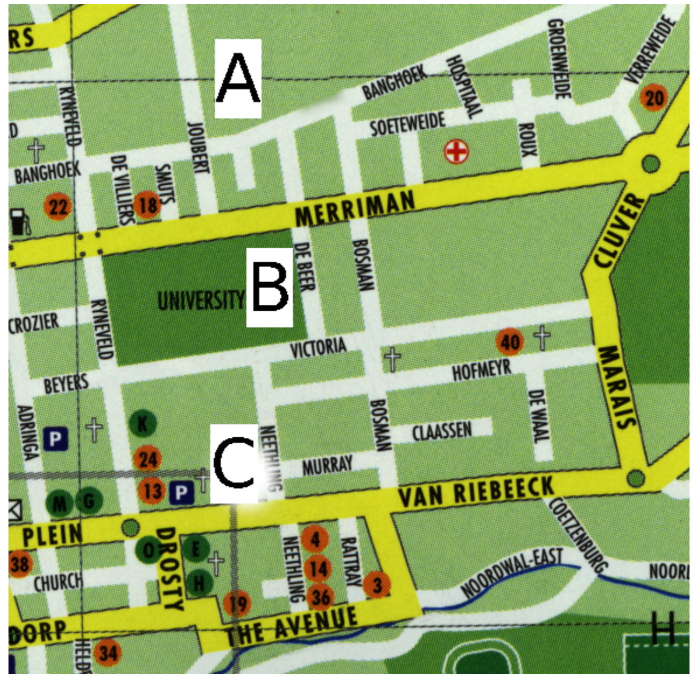
Registration, lectures and tea breaks

Registration is on Monday 2 April 2007 from 08:00 to 08:50 in the foyer of the general engineering building (on the corner of Banghoek and Joubert roads, marked A on the map below). All tea breaks will also be held in the foyer of the general engineering building.



Lunches

Lunch will be at Die Bloukamer, in the Neelsie student center (marked B on the map) and are included for all conference participants.

Reception

Drinks and light snacks will be served between 08h00 and 20h00 at Katjiepiering Restaurant in the Stellenbosch botanical gardens (marked C on the map).

Conference Dinner

The conference dinner is on Tuesday, 03 April 2007 at Restaurant Barrique at Vredenheim Estate. We will leave from the parking in front of the general engineering building at 18:00 to arrive at the restaurant at 18:30. Those who need a lift and those who can offer a lift must please meet in front of the general engineering building. Note that the conference dinner is not included in the student registration fee.

Email

Details of email and internet facilities will be announced.

Monday 2 April

FIRST-ORDER SYSTEM LL* (FOSLL*) FOR MAXWELL'S EQUATIONS IN 3D WITH EDGE SINGULARITIES

Tom Manteuffel (University of Colorado at Boulder, USA)

The L2-norm version of first-order system least squares (FOSLS) attempts to reformulate a given system of partial differential equations so that applying a least-squares principle yields a functional whose bilinear part is H1-elliptic. This means that the minimization process amounts to solving a loosely coupled system of elliptic scalar equations. An unfortunate limitation of the L2-norm FOSLS approach is that this product H1 equivalence generally requires sufficient smoothness of the original problem. Inverse-norm FOSLS overcomes this limitation, but at a substantial loss of real efficiency. The FOSLL* approach described here is a promising alternative that is based on recasting the original problem as a minimization principle involving the adjoint equations.
This talk provides a theoretical foundation for the FOSLL* methodology and application to the eddy current form of Maxwell's equations. It is shown that singularities due to discontinuous coefficients are easily treated. However, singularities due to reentrant edges require a further modification. A partially weighted norm is used only on the slack equations. The solution retains optimal order accuracy and the resulting linear systems are easily solved by multigrid methods.
Comparison is made to the curlcurl formulation and the weighted regularization approach. The FOSLL* is shown to have equal or better accuracy, obtained at a smaller cost. Numerical examples are presented that support the theory.

EXPLICIT TWO-STEP PEER METHODS

Weiner, Rüdiger (University of Halle)
Podhaisky, Helmut (University of Halle)
Schmitt, Bernhard A. (University of Marburg)

Over the last years two-step peer methods for stiff and nonstiff differential equations have been intensively studied, both for sequential and parallel implementation. Linearly-implicit and implicit two-step peer methods combine good stability properties with a high stage order, making them attractive for very stiff problems. We give an overview about construction, stability and order results of these methods. In more detail we discuss s-stage explicit two-step peer methods for nonstiff differential equations. We give order conditions and present a construction principle for methods of order p=s. By a special choice of the parameters we obtain optimal zero stability. An additional condition allows to obtain superconvergence of order p=s+1 for variable stepsizes. We present numerical results for explicit two-step methods on some well-known test problems and compare our methods with the state of the art codes DOPRI5 and DOP853. The results show the efficiency of the two-step methods. Furthermore we consider a special subclass of these methods, where all s stages can be computed in parallel with s processors.

NUMERICAL ANALYSIS OF VARIATIONAL INEQUALITIES

Daya Reddy (University of Cape Town, South Africa)

Variational inequalities arise in a great many applications in the physical sciences and engineering, often in the context of weak or variational formulations of problems posed on convex sets rather than on subspaces of functions, and of problems involving differential inclusions rather than equations. The aim of this talk is, first, to present an overview of some typical elliptic variational inequalities arising in physics and engineering. The second and main objective of the talk is to explore the properties of finite element approximations of particular classes of these variational inequalities, and to construct, analyse and illustrate recently developed algorithms that are well suited to the solution of such problems.

COMPARISON OF LINEAR BEAM THEORIES

Anneke Labuschagne (University of Pretoria)

anneke.labuschagne@up.ac.za

Three models for a cantilever beam based on different linear theories are considered; the Euler-Bernoulli, Timoshenko and two-dimensional elasticity theory. Using natural frequencies and modes of vibration as a yardstick, the conclusion is that the Timoshenko theory is close to the two-dimensional theory for modes of practical importance, but that the applicability of the Euler-Bernoulli theory is seriously limited.

THE USEFULNESS OF THE EULER-BERNOULLI THEORY FOR THE VIBRATIONS OF A BEAM

Inger Plaskitt (University of Pretoria)

inger.plaskitt@up.ac.za

The well known Euler-Bernoulli theory for the vibration of a beam was improved by Timoshenko in 1921. Since then numerous studies have yielded convincing results that the Timoshenko theory is indeed a great improvement. Nevertheless, the Euler-Bernoulli theory is still widely used and the question is when this can be justified. Since both mathematical models are linear, comparison of natural frequencies is usually considered to be sufficient. However, what is really required is to determine the difference between solutions resulting from the same disturbance. We discuss the complications involved in such an investigation and present some results.

VIBRATIONS OF A BEAM BETWEEN OBSTACLES: CONVERGENCE AND SIMULATION OF A FULLY DISCRETIZED APPROXIMATION

Y. Dumont (University of Reunion Island (France))

L. Paoli (University of Saint Etienne (France))

Yves Dumont (University of Saint Etienne (France))

We study the motion of an elastic beam which is clamped at its left end to a vibrating support and which can move freely at its right end between two rigid obstacles. The contact is modelled with Signorini's complementary conditions for the displacement and the shear stress. For this infinite dimensional impact problem we propose a family of fully discretized approximations dealing directly with the unilateral boundary conditions, which convergence is proved. The results given here are also valid in the case of a beam oscillating between two longitudinal rigid obstacles. Some numerical results are presented and compared to the approximate solutions obtained with a penalty approach.

APPLICATION OF SINGULAR PERTURBATION METHODS TO THE SOLUTION OF POLYNOMIAL EQUATIONS

D P Mason (School of Computational and Applied Mathematics, University of the Witwatersrand, Johannesburg, Sout)

dpmason@cam.wits.ac.za

Two applications of singular perturbation methods to the solution of polynomial equations will be described. The first application is to the inflation of a thin-walled spherical shell in finite elasticity. As the extension increases and if a condition is satisfied, the inflation pressure first increases, reaches a maximum value and then decreases to a minimum value before again increasing steadily. Inflation with a decrease in pressure is referred to as snap buckling. The stretch at the turning points of the pressure satisfies a fourth degree polynomial equation with a small parameter multiplying the term of highest degree. The perturbation solution of this fourth degree polynomial equation is described. The second application is to slow viscous flow past a liquid drop. The Reynolds number for which standing eddies first appear downstream of the liquid drop satisfies a cubic equation. Although the small parameter does not multiply the highest degree term it is a singular perturbation problem. The perturbation solution of the cubic equation for the Reynolds number is described.

HIGH FREQUENCY INDUCED INSTABILITY IN SOME NON LINEAR NUMERICAL SCHEMES

S.W. Schoombie (University of the Free State)

E Mare (University of Pretoria)

When applying Nystrom methods to the van der Pol equation, a high frequency mode sooner or later causes severe instabilies. The onset of these can be delayed by decreasing the time step. Thus, when the purpose of the computation is to find the limit cycle, there is an effective upper limit to the time step, which gets lower with higher order schemes. This phenomenon is not limited to the van der Pol equation, but can also be observed in a predator prey system with a limit cycle. Equations like the Duffing equation seems to be free of this instability for the second order scheme.

CRITICISM OF ASYMPTOTIC GLOBAL ERROR EXPANSION AND A NEW THEORY OF EXTRAPOLATION METHODS

Gennady Kulikov (University of the Witwatersrand, Johannesburg)

gkulikov@cam.wits.ac.za

In this paper we discuss existence of the asymptotic global error expansion for numerical solutions obtained from general one-step methods applied to ordinary differential equations. The asymptotic global error expansion was discovered independently by Henrici, Gragg and Stetter in 1962, 1964 and 1965, respectively. It is an important theoretical background for extrapolation methods. We draw attention to some flaws in that theory and show that such an expansion is likely to fail to work in practice. Therefore we give another substantiation for extrapolation methods. The Richardson extrapolation technique is a key means to explain how extrapolation methods perform. Additionally, we prove that the Aitken-Neville algorithm works for any one-step method of an arbitrary order s under suitable smoothness.

ELEMENTARY STABLE AND DISSIPATIVE NUMERICAL SCHEMES FOR DYNAMICAL SYSTEMS

Jean M-S Lubuma (University of Pretoria)

jean.lubuma@up.ac.za

We analyze non-standard finite difference schemes that have no spurious fixed-points compared to the dynamical system under consideration, the linear stability/instability property of the fixed-points being the same for both the schemes and the continuous system. For more complex systems, which are dissipative, we design schemes that replicate this property.

APLLICATION OF THE METHOD AF ADDITIONAL CONDITIONS TO THE NEUMAN PROBLEM FOR THE LAPLACE EQUATION IN THE ANGLE DOMAIN

Neugebauer Igor (Department of Applied Mathematics, National University of Rwanda)
Newigor52r@yahoo.com

The method of additional conditions can be used in the classical boundary value problems of mathematical physics which can give some non-physical solutions with singularities. There were considered the classical Griffiths problem for linear elastic plane under tension. The presented method gave the finite stresses near the tip of a crack which value corresponds to the information about experiments of Griffiths and Inglis. There was considered the classical Dirichlet problem for Laplace equation in the angle domain. The obtained first approximate solution gave the nonsingular solution in the domain with obtuse angles where usually exist the singular solution of the standard Dirichlet problem. The obtained solution depends continuously on the angle of the domain. Here in this talk will be considered the Neuman problem for the Laplace equation in the angle domain. The obtained first approximation of the solution gives the nonsingular solution in the domain with the obtuse angle. This solution depends continuously on the angle of the considered domain.

MAXIMUM LIKELIHOOD ESTIMATION USING SQUARE-ROOT COVARIANCE FILTER

Maria V. Kulikova (University of the Witwatersrand, Johannesburg)
mkulikova@cam.wits.ac.za

In this paper we consider a discrete-time linear stochastic system and discuss the problem of Maximum Likelihood Estimation (MLE) of unknown system's parameters. MLE requires maximization of the Likelihood Function that is often done by using a gradient approach starting from some *a priori* values. Thus, to apply a gradient-search optimization technique, computation of the Log-Likelihood Gradient (LLG) is necessary. This problem leads to implementation of a Kalman filter (and its derivative with respect to each parameter), which is known to be unstable. As a consequence, any method of evaluation of LLG based upon the conventional Kalman filter implementation inherits its pitfalls and, hence, cannot be considered as numerically stable. Here, we discuss the problem of efficient evaluation of LLG and present some new square-root algorithms based upon the covariance forms of Square-Root Filters. By constructing our methods, we add a new feature to the underlying filters that allows the Log-Likelihood Function and its gradient (with respect to unknown parameters) to be computed simultaneously. Thus, these new algorithms are ideal for simultaneous state estimation and parameter identification. With the theoretical results we give examples of ill-conditioned problems and show that our methods outperform the conventional approach for accuracy.

THE EFFICIENCY OF AN ADAPTIVE ALGORITHM FOR THE SIMULATION OF DIFFUSIONS

Jack Urombo (Department of Mathematical Sciences, Faculty of Engineering Sciences, Harare Institue of Technology)
jurombo@hit.ac.zw

We develop an adaptive method for the simulation of solutions of stochastic differential equations. The algorithm controls the approximation error and minimises the amount of computational work.
We test the algorithm on both implicit and non implicit schemes for a certain class of stocahstic differential equations.

Tuesday 3 April

RECONSTRUCTION OF POROUS MEDIA AND TRANSPORT ON THE PORE SCALE

Pierre Adler (University of Paris VI (Sisyphe), France)

The quantitative study of real porous media on the pore scale necessitates two steps, namely to simulate realistic media and to calculate the desired transport properties in these structures. This procedure and this point of view have now invaded the literature thanks to the simultaneous development of a powerful measurement device the microtomograph.
The realistic simulation of porous media was initiated in 1990 with the reconstruction of a Fontainebleau sandstone. This standard reconstruction procedure will be briefly recalled. Its advantages and limitations will be pointed out. Then, it will be shown how this technique can be used to generate media with complex structures such as media with variable porosity, with several lengths scales... Random packings will also be addressed.
In order to calculate the transport properties, the relevant local partial differential equations must be solved, for instance the resolution of the Stokes equation yields the permeability of the medium. Elementary examples will be addressed to demonstrate the methodology.
Then, the complex case of multiphase flows will be detailed with deposition of a solute. These fluids contain most of the times solutes which may deposit onto the solid walls. This deposition onto the walls may have two consequences that we have studied separately. In the first case, the solid phase is increased by deposition; porosity is progressively decreased until clogging occurs and stops the flow and the deposition process; during this stage all the quantities such as the absolute permeability and the relative permeabilities vary as function of time; such a situation is common in formation damage.
To conclude, various recent studies will be mentioned.

TRANSIENT FLOW THROUGH POROUS BARRIERS.

Beric Skews (University of the Witwatersrand)
beric.skews@wits.ac.za

A programme of experimental studies on shock wave induced transient flow through porous materials has been undertaken. Materials tested range from permeable grids, textiles, rigid porous blocks, and elastic porous foams, for both head-on and inclined cases of shock wave impact. Examples of some of these will be illustrated. Interesting effects occur for the foam and textile cases if positioned on or adjacent to a wall, in that significant wall pressure amplification can occur. Many experiments have been conducted and numerical models formulated in the past in order to elucidate the processes occurring. A recent review of these has been given in [1]. The numerical models give results showing a reasonably close physical representation of the experimentally determined motion, although they rely on complex models and computational methods and nearly always require empirical adjustment to match the experiments. There appears to be a need for a simple analytical model in order to extract the primary physical factors of importance rather than including the multiplicity of foam properties in empirical numerical and physical experiments.
A simple model is proposed to describe the main features for the case of a collapsing foam block. The complex two-phase interactions can be simplified using the experimental evidence that the foam face may be treated as a contact surface, that the length of the compacted foam plug grows linearly in time, and that the gas pressure profile in the region between the head of the plug and the undisturbed material may be treated as being pseudo-stationary. These simplifications enable the prominent features of the compression process to be predicted for a variety of foam types.

References

1. Skews BW, Levy A, Levi-Hevroni D. Shock wave propagation in porous materials. In: Handbook of Shock Waves. Ben-Dor G, Igra O, Elperin T. (Eds.), Academic Press. 545-596, 2001

SCATTERED DATA APPROXIMATION BY RADIAL BASIS FUNCTIONS

Armin Iske (Department of Mathematics, University of Hamburg)

iske@math.uni-hamburg.de

Radial basis functions are powerful methods for approximation of scalar-valued and vector-valued multivariate functions from scattered data. This talk first surveys basic features of scattered data approximation by radial basis functions, before recent advances concerning the method's stability, local approximation properties, adaptivity, and efficient implementation are explained. In this discussion, special emphasis is placed on reconstruction by polyharmonic splines. In particular, the suitability of polyharmonic spline reconstruction for multiscale simulation by meshfree particle methods is shown. Supporting numerical examples arising from real-world application scenarios are presented.

THE HIGHLIGHT THEOREM IN THE DIGITAL PULSE TRANSFORM

Dirk Laurie (University of Stellenbosch)

Carl Rohwer (University of Stellenbosch)

In 2005, Carl Rohwer, with co-author J P Harper, gave a talk at SANUM entitled "The Highlight Conjecture in LULU-transforms". In this talk, the conjecture is proved.

Reference

[Roh2004] C H Rohwer, Nonlinear Smmothing and Multiresolution Analysis. Birkhäuser, Basel, 2004.

APPROXIMATION PROBLEMS AROUND THE DISCRETE PULSE TRANSFORM

Carl Rohwer (University of Stellenbosch)

chr@sun.ac.za

The Discrete Pulse Transform (DPT) yields a Multiresolution Decomposition of a sequence into resolution levels on the edge of sets of locally monotone sequences. This transform meets the requirements, as interpreted by Meyer, for a long standing representation problem of Marr. There are several interesting non-standard Approximation problems connected with the success of the DPT. Some crucial results are explained and open problems are presented.

ON THE DEFINITION OF HYDRODYNAMICAL ENTRANCE LENGTHS IN STRAIGHT DUCTS

S Woudberg (Applied Mathematics, Stellenbosch University)

JP du Plessis (Applied Mathematics, Stellenbosch University)

J Legrand (GEPEA, Universite de Nantes, France)

In the mathematical modelling of transfer processes and dispersion in micro-fluidic devices and porous media the concept of piecewise straight duct sections is of considerable importance. In each section flow is developing from a certain inlet velocity profile towards a fully developed profile. Due to the short sections the flow will be mostly in the developing stage, rendering it an important field of study. In this contribution some views on currently used definitions of entrance lengths and an alternate definition in terms of asymptotic solutions will be discussed.

PERMEABILITY PREDICTION OF FONTAINEBLEAU SANDSTONE

S Woudberg (University of Stellenbosch)
JP du Plessis (University of Stellenbosch)

The microscopic geometry of Fontainebleau sandstone is approximated in the literature as either being predominantly granular or consolidated with tube-like pores. Two pore-scale models, based on rectangular geometry, are used to predict the permeability of Fontainebleau sandstone and the results compared to experimental data. The occurrence of blocked throats at very low porosities is accounted for in the analytical modelling procedure by the introduction of a percolation threshold porosity and the application of an asymptote matching technique. It is found that although both granular and foamlike models yield plausible results, the granular model appears to be somewhat better, at least for the sets of data considered. The Klinkenberg correction is derived analytically and incorporated into the models to relate gas and liquid permeabilities.

LULU OPERATORS FOR FUNCTIONS OF CONTINUOUS ARGUMENT

Carl Rohwer (University of Stellenbosch)
Roumen Anguelov (University of Pretoria)

The LULU operators, fundamental in the nonlinear multiresolution analysis of sequences, are extended to functions defined on a a real interval. We show that the extended operators replicate the essential properties of their discrete counterparts. More precisely, they form a fully ordered semi-group of four elements, preserve the local trend and the total variation.

WAVELETS BASED ON LOCAL PROJECTION OPERATORS I

Johan de Villiers (University of Stellenbosch)
Désirée Moubandjo (University of Stellenbosch)

The study of refinement pairs $(a\,,\phi)$, with a denoting a refinement mask, and where ϕ is the corresponding refinable function, is of fundamental importance in both subdivision and wavelet analysis, as used extensively in the application areas of, respectively, geometric modelling and signal analysis.
We start here with a given refinement pair $(a\,,\phi)$, and build a theory based entirely on time-domain methods, to eventually yield a wavelet decomposition technique with finite algorithms, and with the ability to efficiently detect local irregularities (or non-smoothness) in a given signal. In part I, we prove that, for every resolution level $r \in \mathbb{Z}$, the presence of zero of order N at -1 in the corresponding refinement mask symbol A guarantees that all polynomials of degree $\leq N-1$ are contained in the refinement space $V^{(r)}$ spanned by the integer shifts of $\phi(2^r\cdot)$. In the process, a fundamental identity for the ϕ-commutator operator, as well as a generalised Marsden identity, are obtained. Our results hold for a larger class of refinement pairs than was established before by means of Fourier transform methods where ϕ was assumed to also satisfy properties like integer shift independence, Riesz-stability and/or bounded variation. A quasi-interpolation operator $\mathcal{Q}_r$ mapping , for every $r \in \mathbb{Z}$, real-valued functions on $\mathbb{R}$ into $V^{(r)}$, such that polynomials in Π_{N-1} are reproduced , is then explicitly constructed.

WAVELETS BASED ON LOCAL PROJECTION OPERATORS II

Désirée Moubandjo (University of Stellenbosch)
Johan de Villiers (University of Stellenbosch)

Following the settings of part I, we characterise a local linear projection operator sequence $\{\mathcal{P}_r : r \in \mathbb{Z}\}$, where $\mathcal{P}_r : V^{(r+1)} \to V^{(r)}$, $r \in \mathbb{Z}$, by means of the Laurent polynomial solution Λ of a certain Bezout identity based on the refinement mask symbol A. In particular, it is shown that, provided A possesses no symmetric zeros, and $A(0) \neq 0$, there does indeed always exist such a Laurent polynomial Λ of minimal length. Next, we define the error space sequence $\{W^{(r)} : r \in \mathbb{Z}\}$ by $W^{(r)} = \{f - \mathcal{P}_r f : f \in V^{(r+1)}\}$, $r \in \mathbb{Z}$, and constructively, by means of solving more Bezout identities, show the existence of a finitely supported function $\psi \in V^{(1)}$ such that, for every $r \in \mathbb{Z}$, $W^{(r)}$ is spanned by the integer shifts of $\psi(2^r \cdot)$. According to our definition, we then call ψ a wavelet. The wavelet decomposition algorithm based on the quasi-interpolation operator $\mathcal{Q}_r$, the projection operator $\mathcal{P}_r$, and the wavelet ψ, is then based on finite sequences, and is shown to possess, for a given signal f, the essential property of yielding relatively small wavelet coefficients in regions where the support interval of $\psi(2^r \cdot -j)$ overlaps with a C^N-smooth region of f. Finally, we show how our theory can be used to deduce the known results on the orthonormal Daubechies wavelets.

COMPUTER-ANALYTIC SOLUTION OF SUBSONIC IRROTATIONAL FLOW OVER A SPHERE

G.D. Thiart (Dept of Mechanical and Mechatronic Engineering, Stellenbosch University)
thiart@sun.ac.za

The analytic solution of the subsonic irrotational flow over a sphere, as a series expansion of velocity potential in terms of even powers of Mach number (the Rayleigh-Janzen method), is available in the literature, but only up to the second-order term. The corresponding stream function solution is only available for the zeroth-order term. The availability of more accurate analytical solutions would be valuable for the purpose of benchmarking in the development of numerical solution methods. An algorithm is developed for the implementation of the Rayleigh-Janzen solution method in a digital computer program. The computer implementation hinges on a derived type that implements a series solution, which was employed in a Fortran 95 computer program to compute the velocity potential and stream function solutions for specific heat ratios ranging from 1.0 to 2.0. Results showing the relationship between specific heat ratio and critical Mach number are presented. These results were computed

ON THE TORTUOSITY OF 2D POROUS MEDIA.

M. Cloete (University of Stellenbosch)
J.P. Du Plessis (University of Stellenbosch)

It is necessary to develop a good understanding of the geometrical properties of porous media, because it plays an important role in the analysis of the transport process through any particular medium. Among these properties is tortuosity (loosely, a measure of the waviness of a bundle of pathlines (or streamlines for stationary flow) through a porous medium). Tortuosity is a very vague concept and there exist many confusing interpretations for it. Also, the inverse of tortuosity will be considered. Similarities and differences regarding the definitions for the average straightness of pathlines, expressed in literature, are examined. A new definition, allowing different channel widths in the streamwise and the transverse flow directions, for the tortuosity is derived from first principles.

SUBDIVISION CONVERGENCE AND HERMITE INTERPOLATION

Guy Blaise Dongmo (University of Stellenbosch)

dongmo@sun.ac.za

We present, separately for the scalar and vector cases, sufficients conditions on the Laurent polynomial mask symbol and the initial iterate for cascade algorithm convergence, and therefore also for refinable function existence and subdivision convergence. Moreover, we obtain explicitly the geometric constant appearing in the estimate for the geometric convergence of the cascade iterates to the corresponding refinable function. For the vector case, we consider an application of our result to the issue of Hermite subdivision convergence. For the scalar case, we apply our result to a one-parameter family of mask symbols to obtain a refinable function existence and subdivision convergence parameter interval, yielding in particular also masks with at least one negative coefficient.

GENERALISED SMOOTHING FACTORS IN REFINEMENT MASK SYMBOLS

Deter de Wet (University of Stellenbosch)

deter@sun.ac.za

We show that traditional smoothing factors of the form (1+z) can be replaced by more general factors allowing us to establish new sufficient conditions concerning the regularity of refinable functions. We can also show the existence of polynomial sections in refinable functions which are not polynomials on some other sections in the support of the function. The results are derived for a general integer dilation factor at least 2.

APPLICATION OF DISCRETE-VELOCITY MODELS IN PRACTICAL FLOW COMPUTATIONS

Dr. Mapundi Kondwani Banda (University of KwaZulu-Natal (PMB))

bandamk@ukzn.ac.za

Discrete-velocity models of mesoscopic kinetic equations are used to design algorithms for flow computations. One of the most common type of a discrete velocity model is the Lattice Boltzmann approach. In the low Mach number limit of the lattice Boltzmann type models the incompressible Navier-Stokes equations are obtained. The same approach is extended to Shallow Water flow. To derive the flow equations from discrete-velocity models asymptotic analysis based on the Chapman-Enskog analysis or diffuse scaling is applied. Moreover, in the course of this analysis, the discrete-velocity models reduce to a relaxation system of equations for macroscopic flow variables which can be discretized using higher-order non-oscillatory upwind relaxation schemes. These approaches offer an alternative to the traditional solvers. The implementation of both these approaches is simple. Numerical computations are carried out on various practical test problems including shallow water flow, incompressible flow with radiative heat transfer and turbulent thermal flows.

SINGULARITY CANCELLATION QUADRATURE SCHEME FOR CURVILINEAR TRIANGULAR DOMAINS

Matthys M. Botha (University of Stellenbosch)

mmbotha@sun.ac.za

Surface integral equations are routinely solved by boundary element methods (BEM's), for scattering analysis. Typically, discretization involves creating a mesh of triangular elements approximating the scatterer's surface, upon which basis functions are defined. Geometrically, these elements can be either rectilinear or curvilinear, with the latter generally yielding more accurate results. In the BEM, the product of the Green function (typically with order $1/\mathrm{R}$ singularity) with any given basis function is routinely integrated over the support of the basis function, for wide ranging observation points. These integrals can be very difficult to evaluate in the near-singularity case. Recently, a new singularity cancellation quadrature scheme has been proposed by Wilton et al., for the numerical integration of $1/\mathrm{R}$ near-singularities on rectilinear triangles. In this presentation, the scheme will be extended to the general curvilinear case. Also, a theoretical error analysis of the extended scheme as well as standard Gaussian product rule integration will be conducted. Finally, numerical results will be presented.

Tuesday 3 April

FROM TSUNAMIS TO INSECT WAKES: SOLITARY WAVES IN FREE SURFACE FLOWS

Paul Milewski (University of Wisconsin, Madison, USA)

We discuss the various solitary waves that can occur on the surface of water. Solitary waves are waves that decay away from their center and propagate in a given direction without changing their shape. These range from the celebrated solitons of the Korteweg-de Vries equation which occur under the right depth conditions, to newly discovered three dimensional solitary waves occurring on scales where surface tension is important. Examples of observations of solitary waves in a variety of settings will be shown.

MULTI-SCALE MODELLING OF BIOCHEMICAL SYSTEMS BY THE CHEMICAL MASTER EQUATION

Kevin Burrage (University of Queensland)
kb@maths.uq.edu.au

Biochemical reactions underlying genetic regulation are often modelled as a continuous-time, discrete-state, Markov process, and the evolution of the associated probability density is described by the so-called chemical master equation (CME). However the CME is typically difficult to solve, since the state-space involved can be very large or even countably infinite. Until now this has meant that the direct computation of the probability density function (pdf) associated with chemical kinetics that takes into account intrinsic noise has not been computationally feasible. Recently a finite state projection method (FSP) that truncates the state-space has been suggested by Munsky and Khammash and shown to be effective on small scale problems. Presented in this talk is a Krylov FSP algorithm based on a combination of state-space truncation and inexact matrix-vector product routines. This allows larger-scale models to be studied and solutions for larger final times to be computed in a realistic execution time.

We compare the efficiency of this technique with trajectorial approaches such as the Stochastic Simulation Algorithm and also show how a strong trajectory can be computed directly from the pdf computed by the CME. Numerical results indicate that this new approach can be fast and is extendable to large biological models.

This is joint work with Markus Hegland (ANU), Shev Macnamara (UQ), and Roger B. Sidje (UQ).

MODELS FOR BLINK CYCLES OF THE HUMAN TEAR FILM

Richard J. Braun (Mathematical Sciences, University of Delaware, USA)

A. Heryudono, T. Driscoll, L.P. Cook (Mathematical Sciences, University of Delaware, USA)

P.E. King-Smith (College of Optometry, University of Delaware, USA)

Every time one blinks, a tear film is left on the front of the eye. After a brief introduction to the structure of the tear film and the physiology of the anterior eye, we discuss recent models for the tear film formation and evolution over one or more blink cycles. The models employ high-order lubrication-type equations on a moving domain; both finite difference and a spectral-based methods have been applied to solving the problem. We find the latter outperforms the latter, but not dramatically. These models are already contributing to our understanding of the tear film behavior. For example, many blinks are partial in the sense that eyelids don't fully close; results show that if the eyelids close to about 1/8 of the fully open width, that is enough to fully refresh the tear film. Quantitative comparison with in vivo tear film thickness measurements for half blinks will be discussed as well.

APPROXIMATIONS OF NONLINEAR PHENOMENA ARISING IN ANGULAR DEVIATION OF LIGHT RAYS THAT EMERGE FROM PRISMS

Shirley Abelman (University of the Witwatersrand, Johannesburg)

Herven Abelman (University of the Witwatersrand, Johannesburg)

Monochromatic light rays incident from some directions on a glass prism emerge from the prism with their direction changed. For many thick prisms emerging light rays are obscured at a boundary. The purpose of this talk is to show that particular light ray deviations can be approximated by polynomials of varying degree over a domain of incident angles. The angles of deviation depend on the apex angle, the direction of incidence with respect to the prism and the material of the prism. For a prism in air, the incident direction is allowed to vary for a chosen range of apex angles. For each apex angle value and each incident direction, the corresponding ray deviation values are calculated. The theoretical equations for the extremes of angular deviation are nonlinear and awkward to use. Because of their ease of application and goodness of fit, polynomials of varying degree and nature are chosen to approximate these nonlinear equations. Graphical comparisons are made between these ap-

UNSTRUCTURED HIGH ORDER NODAL FINITE ELEMENTS TO SOLVE THE BIDOMAIN EQUATIONS

Nicolas Jeannequin (Computing Laboratory, Oxford University)

nicolas.jeannequin@new.ox.ac.uk

In this talk we will describe an explicit method for the construction of nodes that are suitable for polynomial interpolation on simplices. These nodes show a performance on par with Fekete and electrostatic nodes up to 12th order, but their very simple construction makes them much more desirable. I will then present a novel application of these nodes: a pseudo-spectral scheme on unstructured simplices to solve the bidomain equations. The bidomain model describes the macroscale electrical activity of cardiac tissue and is coupled to a cellular model, such as the Luo-Rudy '91 model.

A HYDRA OF SINGULARITIES AND HARMONIC SUBSERIES

Thomas Schmelzer (Oxford University Computing Laboratory, Balliol College)

thomas-schmelzer@gmx.de

In the tradition of the SIAM 100-Digit challenge I will attack two problems that have been posed by Brian Davies and Folkmar Bornemann. Davies cooked up a rather nasty oscillating integral as a problem that would involve serious difficulties both analytically and numerically. Bornemann raised the question about the limit of the harmonic series when omitting all terms that contain the substring “42”.

A NON-POLYNOMIAL SPLINE BASED FAMILY OF METHODS FOR SOLUTION OF ONE-DIMENSIONAL DIFFUSION EQUATION

Siraj-ul-Islam (University of Engineering & Technology Peshawar (NWFP), Pakistan)

sirajuet@yahoo.com

In this paper a new approach based on non-polynomial spline approximation to the one-dimensional heat conduction equation is discussed. This approach corresponds to the cubic spline approximation by Papamichael & Whiteman and to a finitedifference scheme considered by Saulyev. The non-polynomial spline space considered in this paper consists of polynomial and a trigonometric part. Free parameter introduced in the trigonometric part of the non-polynomial spline is used to improve the accuracy of the scheme, while the trigonometric part of the non-polynomial spline function compensates for loss of smoothness inherited by polynomial splines. Also the algorithm developed by the use of non-polynomial splines leads to the generalization of the algorithm developed by Papamichael & Whiteman which is based on cubic splines and the unconditionally stable finite-difference schemes like Laasonen formula, Crank-Nicolson scheme and Crandalls implicit formula. The spline approximation produces at each time level a spline function which may be used to obtain the solution at any point in the range of the space variable. The procedure to find best values of the parameters is shown and problems from the literature for both homogenous and non-homogenous cases are considered to test the practical usefulness of the method

A CUBIC HEAT BALANCE INTEGRAL METHOD FOR ONE-DIMENSIONAL MELTING OF A FINITE THICKNESS LAYER

Dr. Sarah Mitchell (The University of Cape Town)

Professor Tim Myers (The University of Cape Town)

This work concerns the one-dimensional melting of a finite thickness layer. A series solution describes the temperature in the melt regions. In the solid region the thermal boundary layers are approximated by a cubic polynomial. Results are compared with the exact solution for a semi-infinite block, and shown to agree to within less than 1%. The method is then applied to a situation where no analytical solution is available. A finite thickness frozen solid is placed on a warm substrate in a warm environment: initially the base of the solid heats to the melting temperature when a single melted region develops and subsequently a second melting front appears on the top boundary. We also present an example relevant to heating an ice layer from below, which occurs with de-icing systems.

MATHEMATICAL MODELLING OF METAL SAMPLE TREATMENT WITH COOLING SYSTEM

I. Fedotov (TUT)

T. Fedotova (WITS)

M. Shatalov (CSIR)

One of the most effective method of metal surface thermal strengthening is their laser treatment. Very often the choice of treatment mode is a result of length and very expensive industrial testing including a big number of parameters which are changing at various levels. Creation of a mathematical model of that process allows to significantly decrease the expenses and cut the time of process optimization of laser thermal treatment of metal samples. In the present work the authors present a mathematical model of laser treatment with cooling based on three-dimensional heat transfer equation using Greens function. For Greens function we used the source method which has the property of rapid convergence at small time of transfer process. It is shown that the combination of laser heating method and synchronous cooling improves the microstructure of the treated metal layer through cutting the time of austenite to martensite conversion to minimum.

AN ALGORITHM FOR APPROXIMATE RENYI DIMENSIONS FROM DATA ON MULTIFRACTAL DENSITIES.

Henri Laurie (UCT)

Edith Perrier (IRD)

The basic intuition about multifractals is that they are densities with detail at all spatial scales. We define the spectrum of Renyi dimensions D(q) of a multifracta, given an algorithm for calculating D(q) from density data, and test the algorithm on a density for which D(q) is analytically known. If time permits we will briefly discuss an application to data on species richness in Cape Proteaceae and southern African birds.

DETECTING DISCONTINUITIES FROM SPECTRAL DATA, POLYNOMIAL FILTERING AND THE PRACTICAL RESOLUTION OF THE GIBBS PHENOMENON

Alvaro R. de Pierro (State University of Campinas, Department of Applied Mathematics)
alvaro@ime.unicamp.br

Many practical problems require the reconstruction of a piecewise smooth function from its Fourier coefficients (Nuclear Magnetic Resonance, Fourier inversion in Computed Tomography, Fourier methods for Conservation Laws Differential Equations and many others). It is well known that the convergence of the Fourier series depends on the function's smoothness. In particular, discontinuities give rise to large oscillations close to the jumps, the so called Gibbs phenomenon. Filtering in the Fourier domain and Gegenbauer expansions have been proposed by several authors (Gotlieb, Shu, Vandeven, Solomonoff) to solve the problem. All these methods assume a precise knowledge of the jumps location and amplitude. Fast methods for this task have been based on the conjugate Fourier series and concentration kernels (A. Gelb and E. Tadmor, J. Sci. Comput., 28, 2-3, 2006 and references therein). Recently, Wei, Martinez and De Pierro (Appl. Comput. Harmon. Anal. 2007) presented a new approach for edge detection from Fourier coefficients, based on a new family of polynomial filters (M. Wei, A.R. De Pierro and J. Yin, IEEE Trans. on Signal Proc., 53, 1, 136-146, 2005 and references therein) that proves to be much more accurate and stable than previous approaches. In this talk we briefly describe the new polynomial and spline based filters introduced by Wei, De Pierro, Martinez and Yin, their application to develop methods for edge detection from spectral data and how to use them for the practical resolution of the Gibbs phenomenon. We illustrate the new approach with numerical experiments.

TRACKING WITH ACTIVE APPEARANCE MODELS

McElory Hoffmann (Applied Mathematics, University of Stellenbosch)
mcelory@dip.sun.ac.za

Active appearance models (AAMs) provide a framework for tracking the shape and texture of an object. However, deterministic tracking with AAMs is not robust. For this reason, AAMs are combined with a particle filter in order to increase the robustness. This combination can be achieved in two ways: a direct combination or by combining AAMs with active contours. Encouraging results are obtained.

INCREASED RESOLUTION METHODS

Stéfan van der Walt (University of Stellenbosch)
stefan@sun.ac.za

A polygon-based interpolation algorithm is presented for use in stacking RAW CCD images. The algorithm improves on linear interpolation in this scenario by closely describing the underlying geometry. 25 frames are stacked in a comparison. When stacking images, it is required that these images are accurately aligned. We present a novel implementation of the log-polar transform that overcomes its prohibitively expensive computation, resulting in fast, robust image registration. This is demonstrated by registering and stacking CCD frames of stars taken by a telescope.

Attendees

	Name	Surname	Affiliation	Email
1	Chama	Abdoulkadri	Africa Institute for Mathematical Sciences	chama@aims.ac.za
2	Shirley	Abelman	University of the Witwatersrand	abelman@cam.wits.ac.za
3	Pierre	Adler	University of Paris VI (Sisyphe), France	adler@ipgp.jussieu.fr
4	Saheed	Akindeinde	Africa Institute for Mathematical Sciences	saheed@aims.ac.za
5	Mapundi	Banda	University of KwaZulu-Natal	bandamk@ukzn.ac.za
6	Matthys M.	Botha	University of Stellenbosch	mmbotha@sun.ac.za
7	Ilyes	Boulkabeit	Africa Institute for Mathematical Sciences	ilyes@aims.ac.za
8	Richard	Braun	University of Delaware, USA	braun@math.udel.edu
9	Bernard	Broens	University of Stellenbosch	13903136@sun.ac.za
10	Kevin	Burrage	University Queensland	kb@maths.uq.edu.au
11	Vasco	Chikwasha	Harare Institute of Technology, Zimbabwe	vchikwasha@hit.ac.zw
12	Richard	Clark	University of Stellenbosch	13197967@sun.ac.za
13	Marèt	Cloete	University of Stellenbosch	mcloete@sun.ac.za
14	Hanno	Coetzer	University of Stellenbosch	jcoetzer@sun.ac.za
15	Alvaro	de Pierro	State University of Campinas	alvaro@ime.unicamp.br
16	Johan	de Villiers	University of Stellenbosch	jmdv@sun.ac.za
17	Deter	de Wet	University of Stellenbosch	deter@sun.ac.za
18	Blaise	Dongmo	University of Stellenbosch	dongmo@sun.ac.za
19	Elsa	du Plessis	University of Stellenbosch	14275899@sun.ac.za
20	Prieur	du Plessis	University of Stellenbosch	jpdp@sun.ac.za
21	Wilna	du Toit	University of Stellenbosch	wilna@sun.ac.za
22	Yves	Dumont	University of Reunion Island	Yves.Dumont@univ-reunion.fr
23	Igor	Fedotov	University of the Witwatersrand	fedotovi@tut.ac.za
24	Tatiana	Fedotova	University of the Witwatersrand	Fedotova.Tatiana@wits.ac.za
25	Andreas	Hafver	University of Stellenbosch	14590107@sun.ac.za
26	Ben	Herbst	University of Stellenbosch	herbst@sun.ac.za
27	McElory	Hoffmann	University of Stellenbosch	mcelory@dip.sun.ac.za
28	Karin	Hunter	University of Stellenbosch	karin@sun.ac.za
29	Armin	Iske	University of Hamburg, Germany	iske@math.uni-hamburg.de
30	Siraj-ul-Islam	Islam	University of Engineering and Technolgy, Pakistan	sirajuet@yahoo.com
31	Nicolas	Jeannequin	Oxford University	nicolas.jeannequin@new.ox.ac.uk
32	Sarah Jane	Johnston	University of the Witwatersrand	sjohnston@maths.wits.ac.za
33	Margaret	Kajotoni	Africa Institute for Mathematical Sciences	meg@aims.ac.za
34	Damian	Kajunguri	Africa Institute for Mathematical Sciences	damian@aims.ac.za
35	Gennady	Kulikov	University of the Witwatersrand	gkulikov@cam.wits.ac.za

36	Maria	Kulikova	University of the Witwatersrand	mkulikova@cam.wits.ac.za
37	Anneke	Labuschagne	University of Pretoria	anneke.labuschagne@up.ac.za
38	Dirk	Laurie	University of Stellenbosch	dpl@sun.ac.za
39	Henri	Laurie	University of Cape Town	henri.laurie@uct.ac.za
40	Jean M-S	Lubuma	University of Pretoria	jean.lubuma@up.ac.za
41	Roland	Makala	Africa Institute for Mathematical Sciences	roland@aims.ac.za
42	Tom	Manteuffel	University of Colorado at Boulder, USA	tmanteuf@grandstand.colorado.edu
43	Milton	Maritz	University of Stellenbosch	mfmaritz@sun.ac.za
44	David P	Mason	University of the Witwatersrand	dpmason@cam.wits.ac.za
45	Paul	Milewski	Mathematics, Univ. of Wisconsin	paul_milewski@hotmail.com
46	Sarah	Mitchell	University of Cape Town	sarah@maths.uct.ac.ca
47	Hisham	Mohamed	Africa Institute for Mathematical Sciences	hisham@aims.ac.za
48	Ebrahim	Momoniat	University of the Witwatersrand	ebrahim@cam.wits.ac.za
49	Désirée	Moubandjo	University of Stellenbosch	dvm@sun.ac.za
50	Neil	Muller	iThemba labs	neil@dip.sun.ac.za
51	Dana	Murray	University of the Free State	murraydm.sci@mail.uovs.ac.za
52	Patrick	Muthivhi	Unknown	thavhakhulu@yahoo.uk
53	Tim	Myers	University of Cape Town	myers@maths.uct.ac.za
54	Igor	Neugebauer	National University of Rwanda	newigor52r@yahoo.com
55	Jean-Medard	Ngnotchouye	Africa Institute for Mathematical Sciences	medard@aims.ac.za
56	Fernando	Nieuwveldt	University of Stellenbosch	fernando@dip.sun.ac.za
57	Joy	Okonkwo	Africa Institute for Mathematical Sciences	joy@aims.ac.za
58	Eric	Okyere	Africa Institute for Mathematical Sciences	eric@aims.ac.za
59	Carel	Olivier	University of Stellenbosch	carel@dip.sun.ac.za
60	Eddy Kimba	Phongi	Africa Institute for Mathematical Sciences	eddy@aims.ac.za
61	Inger	Plaskitt	University of Pretoria	inger.plaskitt@up.ac.za
62	Doriano	Pougaza	Africa Institute for Mathematical Sciences	doriano@aims.ac.za
63	Barton	Profitt	University of Stellenbosch	13600877@sun.ac.za
64	Fabi	Rabarison	Africa Institute for Mathematical Sciences	fabi@aims.ac.za
65	Dimbinaina	Ralaivaosaona	Africa Institute for Mathematical Sciences	naina@aims.ac.za
66	Natacha	Ranariboana	Africa Institute for Mathematical Sciences	natacha@aims.ac.za
67	Christo	Rautenbach	University of Stellenbosch	13821490@sun.ac.za
68	Paul	Razafimandimby	Africa Institute for Mathematical Sciences	paul@aims.ac.za
69	Daya	Reddy	University of Cape Town	daya.reddy@uct.ac.za
70	Carl	Rohwer	University of Stellenbosch	chr@sun.ac.za

71	Chris	Rohwer	University of Stellenbosch	14608774@sun.ac.za
72	Thomas	Schmelzer	Oxford University	thomas.schmelzer@balliol.ox.ac.uk
73	Schalk	Schoombie	University of the Free State	SchoomSW.sci@mail.uovs.ac.za
74	Wynand	Singels	University of Stellenbosch	wynand.singels@gmail.com
75	Beric	Skews	University of the Witwatersrand	beric.skews@wits.ac.za
76	Joseph	Ssebuliba	Africa Institute for Mathematical Sciences	joseph@aims.ac.za
77	Albert	Swart	University of Stellenbosch	aswart@dip.sun.ac.za
78	Eric-Martial	Takougang	Africa Institute for Mathematical Sciences	eric-martial@aims.ac.za
79	Antoine	Tambue	Africa Institute for Mathematical Sciences	antoine@aims.ac.za
80	Gerrie	Thiart	University of Stellenbosch	thiart@sun.ac.za
81	Zola Nigussa	Urgessa	Africa Institute for Mathematical Sciences	zola@aims.ac.za
82	Jack	Urombo	Harare Institute of Technology, Zimbabwe	jurombo@hit.ac.zw
83	Rinske	van der Bijl	University of Stellenbosch	rinske@sun.ac.za
84	Stefan	van der Walt	University of Stellenbosch	stefan@sun.ac.za
85	Barry	van Wyk	University of Stellenbosch	13671162@sun.ac.za
86	André	Weideman	University of Stellenbosch	weideman@sun.ac.za
87	'Rüdiger'	Weiner	Martin-Luther University Halle-Wittenberg, Germany	weiner@mathematik.uni-halle.de
88	Gert	Wessels	University of Stellenbosch	gertwessels@gmail.com
89	Sonia	Woudberg	University of Stellenbosch	woudberg@sun.ac.za
90	Dessalegn	Yizengaw	Africa Institute for Mathematical Sciences	dessalegn@aims.ac.za

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