NumCoop09

in honor of Bernard Philippe for his 60th birthday

Book of Abstracts

Yaounde, Cameroon

March 2nd to 4th, 2009

INRIA

Welcome to the international conference on Numerical methods and North-South cooperation, organized by INRIA and the University of Yaounde 1, in honor of Bernard Philippe for his 60th birthday.

The conference aims to be a forum for an exchange of ideas, insights and experiences in different areas of numerical analysis and high performance computing. Topics include numerical linear algebra, nonlinear problems, inverse problems, numerical schemes for PDE and ODE, etc. Emphasis is also put on mathematical models applied to diverse scientific fields such as biology, epidemiology, geophysics, information retrieval, etc. The NumCoop'09 program contains 28 presentations.

The conference brings together experts from north and south countries developing collaborations and promoting scientific cooperation. A roundtable is devoted to 20 years of exchange between Europe, USA, Africa and Middle-East.

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NumCoop'09 program

Monday	**2 March**		**Chairman**	**Session**	**Authors**
8:30	9:00	Registration, Coffee			
9:00	10:30	Opening session			
10:30	12:00	Talks	**M. Tchuente**	Iterative linear solvers	N. Gmati
11:00					G. Atenekeng + D. Nuentsa
11:30					B. Philippe
14:00	17:30	Talks	**M. Vajtersic**	Finite Volumes	A. Njifenjou
14:30					I. Moukouop
15:00			**M. Vajtersic**	Numerical schemes	S. Moto
15:30					N. Nassif
16:30					F. Z. Nouri
17:00					H. Touré

Tuesday	**3 March**				
9:00	12:00	Talks	**M. Jaoua**	Mathematics for biology	B. Tsanou
9:30					C. Lobry
10:00					T. Sari
11:00					G. Sallet
11:30					R. Sidjé
14:00	17:30	Talks	**N. Nassif**	Inverse problems	E. Canot
14:30					M. Jaoua
15:00					A. Ben Abda
15:30					M. Moakher
16:30			**N. Nassif**	Non-linear problems	A. Griewanks
17:00					R. Aboulaich

Wednesday	**4 March**				
9:00	12:00	Talks	**H. Leroy**	Grid/Web/OS	Y. Jegou
9:30					S. Gallopoulos
10:00					M. Vajtersic
11:00					D. Kourie
11:30					R. Ndoundam
14:00	15:30	*Roundtable*	***C. Lobry***	*North-South Cooperation*	
16:00	17:30	Talks	**S. Gallopoulos**	Computational geosciences	F.-X. Le Dimet
16:30					E. Kamgnia
17:00					J. Erhel
17:30	18:00	Closing session			

Some nonlinear parabolic models in image processing

Authors:

Rajae Aboulaich [a]

The image restoration is a crucial step in image processing. Several filters are developed to remove noise, the most interesting are filters who permits to denoise the image preserving semantically important structures. One class of recent adaptive denoising methods is the nonlinear partial differential equations.

In this work we present some diffusion models which can be used for image restoration [1], [2]. The existence and the uniqueness of the models are discussed and we illustrate their efficiency using some numerical experiments. The signal to noise ratio (SNR) number is used to estimate the quality of the restored images [1], [2],[3] and [4].

References

[1] R. Aboulaich, S. Boujena et E. El Guarmah, *Sur un modèle non linéaire pour le débruitage de l'image*, CRAS, EDP, octobre 2007.

[2] R. Aboulaich, D. Meskine and A. Souissi, *New Models Diffusion in image processing*, Computers and Mathematics with Applications, mars 2008.

[3] R. Aboulaich, S. Boujena and E. El Guarmah, *Nonlinear Parabolic Model in Processing of Medical Image*, Mathematical Modelling of Natural Phenomena, Vol. 3, No. 6, (2008), Medical imaging.

[4] R. Aboulaich, F. Guyomarc'h and M. Ziani, *Nonlinear solvers in image processing*, CARI'08, Rabat, Maroc.

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Parallelisation of GMRES preconditioned by one iteration of multiplicative Schwarz

Authors:

Guy Antoine Atenekeng Kahou [a] Emmanuel Kamgnia [b] Bernard Philippe [c]

This articles proposes an alternative to the parallelization of GMRES preconditioned by multiplicative Schwarz by the technique of coloring adjacent graph to the matrix.

This parallelization implies that the adjacent graph to the matrix is partitioned according to one direction [1]. From this partitioning we can derive an explicit form of splitting of multiplicatif Schwarz.

We use this explicit form in a pipeline for the construction of Krylov subspace basis [2]. The qualities of the pipeline are prevent by avoiding a synchronization points due to the dot product in overall process Arnoldi.

For this reason, we use a version of GMRES which decouples the construction of the space Krylov and QR factorization in the process Arnoldi.

All these algorithms are implemented on standard PETSc and bears the name of GPREMS (GMRES PREconditioned by multiplicative Schwarz).

The tests are performed on problems arising from the simulation of semi conductors and fluid mechanics. This validation confirms the parallel qualities of our code, but also its competitiveness with other preconditioner type domain decomposition as Schwarz additive or additional Schur.

References

[1] G. A. Atenekeng Kahou, L. Grigori and M. Sosonkina, *A partitioning algorithm for block-diagonal matrices with overlap*, Journal of Parallel Computing, 34, pp 332–344, 2008.

[2] G. A. Atenekeng Kahou, E. Kamgnia and B. Philippe, *An explicit formulation of the multiplicative Schwarz preconditioner*, Journal of Applied Numerical Mathematics, 57, pp 1197–1213, 2007.

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[c] INRIA-Rennes, France

Missing boundary data recovering and applications to some inverse problems

Authors:

Amel Ben Abda [a]

We are interested in solving the Cauchy problem for an elliptic equation. Many works have been dealing with this problem during the few last decades. Many approaches have been explored both from the theoretical as well as the numerical viewpoints. Our approach in this talk is strongly linked to control theory: here we propose an approach combining two ideas. First we set the approximate control formulation for the Cauchy problem which is known since Hadamard to be ill-posed. Second we add a fading, through the iterations, regularizing term borrowed from the domain decomposition culture.

The Cauchy problem may also be set in the domain decomposition framework: roughly speaking solving the Cauchy problem is equivalent to solve an interfacial operator involving Poincaré-Steklov type operators. This setting has been widely explored theoretically and numerically in the literature. A bridge between the two approaches is set in in the context of an energy control setting.

Numerical experiments illustrate the efficiency of the different approaches.

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Recovering thermophysical properties of the soil

Authors:

Édouard Canot [a] Mohamad Muhieddine [a,b]

This work presents numerical simulations of the unsteady heat conduction in porous water-saturated soils subjected to intense heating from above. Due to the evaporation of the water, the prediction of the liquid-vapor interface position is difficult. In this simple model, the steam flow in the soil is discarded and we used the apparent heat capacity method [1] which allows us to avoid the tracking of the "dry/wet" front.

The inverse problem consists in the estimation of the thermophysical parameters of the soil. Knowing the temperature history at selected points from the alterated soil, the thermal conductivity, the apparent capacity and the porosity of the soil are simultaneously identified. In order to solve the problem the least squares criterion (in which the sensitivity coefficients appear) has been used [2]. Differentiating this latter criterion with respect to the unknown parameters and using the required minimum condition, we obtain the system of equations which enables us to find the values we are looking for. The so-called sensitivity coefficients must be determined and they will be used to solve the system of equations. After some mathematical manipulations we obtain a system of coupled non-linear equations which is a differential algebraic one.

The spatial discretization of the system is obtained by using the vertex-centered finite volume method. The discretized problem may be written in vectorial form with adequate initial and boundary conditions using the method of lines where space and time dicretizations are considered separatly, leading to a semi-discrete system of implicit differential algebraic equations. The time integration method is performed by the `DASSL` solver which has been used to achieve stability and a prescribed accuracy by adjusting automatically the time step. This latter solver has been modified to support a sparse Jacobian matrix, solving the Newton method by using the `UMFPACK` library. Lastly, to achieve performance, the Jacobian matrix is coded by hand. The code validation stage is based on the comparaison between the numerical results and the synthetic data which shows a good agreement.

References

[1] M. Muhieddine, É. Canot and R. March, *Numerical solution for a 1-D time dependent phase change problem*, Proc. of the WCCM8 and Fifth ECCOMAS, Venice, Italy, June 30-July 4, 2008.

[2] E. Majchrzak and B. Mochnaki, *Identification of substitute thermal capacity of solidifying alloy*, J. of Theoretical and Applied Mechanics, 46(2)(2008), pp 257–268.

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How to compute flow in three-dimensional fracture networks

Authors:

Jocelyne Erhel [a]

Baptiste Poirriez [b] Géraldine Pichot [c] Jean-Raynald de Dreuzy [c]

In fractured rocks, fluid flows mostly within a complex arrangement of fractures. Both the fracture network structure and its hydraulic properties are determined at first order by the broad range of fracture lengths and densities. To handle the observed wide variety of fracture properties and the lack of direct fracture visualization, we develop a general and efficient stochastic numerical model for Discrete Fracture Networks (DFNs) in a 3D computational domain. We present an original conforming mesh generation method addressing the penalizing configurations stemming from close fractures and acute angles between fracture intersections. Flows are subsequently computed by using a Mixed Hybrid Finite Element method (MHFE). We analyze the complexity in size and in time for the computation of flow in 3D DFNs meshed with our method and compare with the complexities for 2D rectangular domains meshed with a regular grid. We find out that complexity in size is similar whereas complexity in time is slightly larger for DFNs than for 2D regular domains [1].

However, the number of cells can be large, especially if the network contains large fractures as well as small fractures. We address this difficulty by introducing a Mortar method to deal with non matching grids between fractures of the network. The idea is to generate mesh in each fracture and to apply interface conditions using a Mortar method. Interface conditions are written by using a Mortar space and by defining a master domain along with a slave domain. We derive the algebraic form of these conditions as well as the algebraic form of laws in each domain. We apply our Mortar method and compare it with the method using matching grids. Results show a fairly good accuracy of the Mortar method [2].

References

[1] J. Erhel, J.-R. de Dreuzy, and B. Poirriez, *Flow simulation in three-dimensional discrete fracture network*, submitted, 2009.

[2] G. Pichot, J. Erhel, and J.-R. de Dreuzy, *A Mixed-Hybrid Mortar Method for solving flow in Discrete Fracture Networks*, submitted, 2009.

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Linear algebra techniques and tools for selected Web-science applications

Authors:

Efstratios Gallopoulos [a,b] V. Kalofolias [b] D. Zeimpekis [b] G. Kollias [b]

Internet Algorithmics and Information Retrieval (IR) have become grand challenge application areas for Numerical Linear Algebra. Important problems include dimensionality reduction of very large datasets, and ranking webpages based on link analysis of the Web graph. In this presentation we discuss some problems from this area paying specific attention to Clustering, Nonnegative Matrix Factorization and ranking of Web pages with emphasis on the necessary Linear Algebra infrastructure. We also describe TMG [1], a useful MATLAB tool that enables the rapid prototyping of algorithms and dataset development in IR and Web-IR.

References

[1] D. Zeimpekis and E. Gallopoulos, *TMG: A MATLAB toolbox for generating term-document matrices from text collections*, in J. Kogan, C. Nicholas, and M. Teboulle, editors, *Grouping Multidimensional Data: Recent Advances in Clustering*, pages 187–210. Springer, Berlin, 2006. See http://scgroup.hpclab.ceid.upatras.gr/scgroup/Projects/TMG/

[a] http://scgroup.hpclab.ceid.upatras.gr/faculty/stratis/stratise.html

[b] Computer Engineering & Informatics Dept., University of Patras, Greece

Total Overlapping Schwarz preconditioners for wave propagation

Authors:

Nabil Gmati [a]

F. Ben Belgacem [b] F. Jelassi [b]

We proposed in a previous work [1, 2], a variant of the Totally Overlapped Schwarz algorithm to approximate iteratively the exact absorbing boundary condition, for exterior problems. Now, that same method may be appropriately used as a numerical zooming device on regions of a particular interest. The Total Overlapping - Schwarz enjoys, then, the ability in computing small structures one wants to capture and the efficiency in obtaining, at a reasonable cost, the behavior of the solution far from the obstacles for infinite domains. The main aim of the talk is to use this modified Schwarz procedure as a preconditioner to Krylov subspaces methods so to accelerate the calculations. A detailed study concludes to a quadratic convergence of the then Schwarz preconditioned GMRES method in two dimensions and of order three halves in three dimensions. Afterward, some analytical and numerical examples are provided that in agreement with the theoretical predictions.

References

[1] F. Ben Belgacem, N. Gmati, M. Fournie et F. Jelassi, *Comment traiter des conditions aux limites à l'infini pour quelques problèmes extérieurs par la méthode de Schwartz alternée*, C. R. Acad. Sci. Paris, Ser. I 336, 277–282 (2003).

[2] F. Ben Belgacem, N. Gmati, M. Fournie and F. Jelassi, *On the Schwarz algorithms for elliptic exterior boundary value problems*, ESAIM-M2AN, Vol 39, N.4, 2005.

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Derivation of a design space preconditioner for one-shot optimization

Authors:

Andreas Griewank [a] Adel Hamdi [a]

We consider the task of minimizing an objective function $f(y,u)$ with $(y,u) \in Y \times U$ the product of two Hilbert spaces subject to a state equation in fixed point form $G(y,u) = y$. The Jacobian $G_y = \partial G/\partial y$ is assumed to have a spectral radius $\rho < 1$ at all points of interest. Then feasible solutions $y = y(u)$ can be computed by the iteration $y_{k+1} = G(y_k, u)$ for $k = 1, \ldots$. We assume that the iteration function G is user supplied and may represent a simple local relaxation method or a sophisticated multigrid scheme [1]. The rate of convergence and thus the computational effort for resolving the state equation with a certain accuracy is determined by ρ or rather $1-\rho$, which may be dependent on discretization parameters like for example the mesh width if the state equation is originally a PDE.

With $L(y,\bar{y},u) \equiv f(y,u) + \bar{y}^\top (G(y,u) - y)$ the Lagrangian of the optimization problem we may append the primal iteration above with a dual iteration and an optimization loop to obtain the coupled system

$$\begin{aligned} y_{k+1} &= y_k + L_{\bar{y}}(y_k, \bar{y}_k, u_k) \\ \bar{y}_{k+1} &= \bar{y}_k + L_y(y_k, \bar{y}_k, u_k) \\ u_{k+1} &= u_k - B_k^{-1} L_u(y_k, \bar{y}_k, u_k) \end{aligned}$$

The key ingredient of this one-shot approach is the design space preconditioner B_k, which must be selected as a symmetric positive definite $n \times n$ matrix in the practical situation $n \equiv \dim(U) < \infty$. Ideally B_k should be defined and computed such that the spectral radius $\hat{\rho}$ of the coupled system is below 1 and as close as possible to ρ.

Based on the theory developped in the papers [2, 3, 4] we have arrived at the tentative conclusion that a fairly optimal choice for B_k is given by

$$B \;\equiv\; \alpha G_u^\top G_u + \beta L_{uy} L_{yu} + L_{uu}$$

Here the weighting coefficients are defined by

$$\alpha \equiv \frac{\|L_{yy}\|}{(1-\rho)^2} + \frac{q}{(1-\rho)} \quad \text{and} \quad \beta \equiv \frac{1}{q(1-\rho)}$$

where

$$q \equiv \max_{0 \neq v \in U} \frac{\|L_{yu} v\|}{\|G_u v\|}$$

The ratio q quantifies the perturbation of the adjoint equation $L_y = 0$ caused by a design variation v relative to that in the primal equation $G - y = 0$. It can be shown that in the vicinity of a fixed point for this $B_k = B$ the coupled system cannot have real eigenvalues outside the open interval $(-1, 1)$. The modulus of complex eigenvalues is still under investigation.

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The given preconditioner may be viewed and practically approximated as second order derivative with respect to the design u of the double augmented Lagrangian

$$L^a(y, \bar{y}, u) \equiv L(y, \bar{y}, u) + \frac{\alpha}{2}\|L_{\bar{y}}\|^2 + \frac{\beta}{2}\|L_y\|^2$$

Globally one can show that this merit function is consistently reduced by the coupled step defined above. We present numerical results on the test problem proposed in [5].

References

[1] A. Brandt, *Multi-Level Adaptive Solutions to Boundary-Value Problems*, Math. Comp. 31 pp 333-390 (1977).

[2] A. Griewank, *Projected Hessians for Preconditioning in One-Step One-Shot Design Optimization*, Large Scale Nonlinear Optimization, vol., p. 151-171 (2006).

[3] A. Hamdi and A. Griewank, *Properties of an Augmented Lagrangian for Design Optimization*, DFG Preprint-Nr. SPP1253-11-01 (2008).

[4] A. Hamdi and A. Griewank, *Reduced Quasi-Newton Method for Simultaneous Design and Optimization*, DFG Preprint-Nr. SPP1253-11-02 (2008).

[5] K. Ito, K. Kunisch, I. Gherman and V. Schulz, *Approximate nullspace Iterations for KKT systems in model based optimization*,

Detection of small flaws locations using topological asymptotic expansion

Authors:

Mohamed Jaoua [a] Amel Ben Abda [b] H. Maatoug [b] M. Masmoudi [c]

The present work deals with the detection of small cavities in Stokes flow from over-specified boundary data. Such a problem arises for example in moulds filling, since the industrial process may generate small gas bubbles which are trapped inside the material while solidifying. The inverse problem aims to locate these defects in order to decide whether the moulded piece is safe or not. The forward problem simulation relies on quite complex and heavy models, based on the incompressible Navier-Stokes equations in the liquid phase, and taking into account the liquid-gas free surface as well as the solidification process.

In this work we assume that the mould is filled with a viscous incompressible fluid and we aim to locate the unknown gas bubbles locations from boundary measurements. The velocity and pressure of the liquid particules are governed by a simplified model based on the Stokes equations. The gas bubbles are modelled as small cavities having an homogeneous Neumann condition on their boundaries.

We rephrase the geometrical inverse problem under consideration into an optimal design one. The optimal design functional to minimize in order to find out the flaws is the misfit, with resp ect to some appropriate norm, between a "Dirichlet" solution based on the measurements, and a "Neumann" one based on the prescribed loads. To minimize this misfit functional we resort the topological gradient method. It consists in studying the sensitivity of the cost function with respect to a small topological perturbation of the domain.

In the theoretical part, we derive a topological sensitivity analysis for the Stokes system with respect to the insertion of a small hole (flaw) in the fluid flow domain with Neumann condition; on the boundary. The obtained results are general and valid for a large class of cost function. The topological sensitivity of the misfit functional with respect to the presence of a "small flaw" is computed, and it turns out to rely only on quantities needing to be computed on the safe domain.

In the numerical part, we propose a simple, fast and accurate identification procedure. The flaws location are obtained as the most negative local minima of the misfit functional sensitivity. The efficiency of the proposed method is illustrated by several numerical experiments. The sensitivity of the proposed method to some numerical parameters or practical possibly occurring situations such as the relative mesh/flaw size, the flaw's depth, the noisy data and the multi-flaws situations are discussed.

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XtreemOS, an Operating System for the Grid

Authors:

Yvon JÉGOU [a] Christine MORIN [a]

The XtreemOS [1] operating system [1] provides for the Grid what a traditional operating system offers for a single computer: abstraction from the hardware and secure resource sharing between different users. It thus simplifies the work of users belonging to virtual organisations by giving them the illusion of using a traditional computer, and releasing them from dealing with the complex resource management issues of a typical Grid environment. When a user runs an application on XtreemOS, the operating system automatically finds all resources necessary for the execution, configures user's credentials on the selected resources and starts the application.

The XtreemOS operating system provides three major distributed services to users: **Application execution management** (providing scalable resource discovery and job scheduling for distributed interactive applications), **Data management** (accessing and storing data in XtreemFS, a POSIX-like file system spanning the Grid) and **Virtual organization management** (building and operating dynamic virtual organizations).

The realization of this new Grid operating system introduces new challenges:

Scalability: supporting hundreds of thousands of nodes and millions of users dynamically joining and leaving the Grid.
Transparency: hiding the complexity of the Grid by distributed operating system services allowing to run new and legacy applications seamlessly.
Interoperability: complying with all major standards such as POSIX and SAGA.
Dependability: providing reliability and high availability through checkpointing and replication.
Security: ensuring trust and integrity according to customizable policies.

This talk will concentrate on the interactions between users and the XtreemOS operating system: managing virtual organizations, running distributed applications and managing data.

References

[1] *The XtreemOS European Project*, http://www.xtreemos.eu/

[2] T. CORTES, C. FRANKE, Y. JÉGOU, T. KIELMANN, D. LAFORENZA, B. MATTHEWS, C. MORIN, L. P. PRIETO and A. REINEFELD. *XtreemOS: a Vision for a Grid Operating System*, XtreemOS technical report #4, http://www.xtreemos.eu/publications/techreports/xtreemos-visionpaper-1.pdf

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[1] XtreemOS IP project is funded by the European Commission under contract IST-FP6-033576

Images as observations in data assimilation

Authors:

Emmanuel KAMGNIA [a]

François-Xavier LE DIMET [b] Innocent SOUOPGUI [a,b] A. VIDARD [b]

Understanding and forecasting the evolution of geophysical fluids (ocean, atmosphere, continental water) is a major scientific and societal challenge. To achieve this goal we need to take into account all the available information. This information can take several forms:

- mathematical information under the form of a set of non linear PDE's;
- physical information: in-situ or remote measurements;
- statistical information;
- qualitative information.

The prediction will be produced by an integration of the model from an initial state, therefore the problem is to retrieve, in a coherent manner, the initial fields from these heterogeneous sources of information. This can be done by using Variational Data Assimilation based on optimal control techniques. Variational Data assimilation is now used by the major meteorological centres. Since several decades many satellites have been launched for the observation of the earth for a better knowledge of the atmosphere and of the ocean. It is clear that the dynamics of the images observed has a strong predictive potential, unfortunately, at the present time, this information is not optimally used in conjonction with numerical models.

The purpose of this presentation is an extension of optimal control to the assimilation of images. Two basic techniques can be considered:

- from the images, based on some law of conservation of luminance, some velocity can be estimated then used as pseudo-observations in a classical scheme of variational assimilation;
- the state variables of the fluids are augmented by objects such fronts, an extended model will include the dynamics of these objects. In the cost function of the variational formulation a quadratic term measuring the discrepancy between computed and observed images is included.

The choice of the space of images will be discussed and some examples presented.

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A statistical safety model of embedded software exposed to electro-magnetic interference

Authors:

Derrick KOURIE [a]

Circumstances may arise in which a safety-critical software system is exposed to electro-magnetic interference that inadvertently causes a life-threatening software failure. Recognising this possibility, two South African companies commissioned a study of a system that activates detonators in mine blasting operations [1]. The objective was to estimate the system's compliance with IEC 6158 — a commonly used International Electrotechnical Commission safety standard.

A model was proposed that takes in account the system's hardware features, the control flow logic of its embedded code, and the assumed nature of interference. The hardware includes a 13-bit program counter, 8-bit and 16-bit registers, and flash memory which stores the embedded C-compiled code. A control flow analysis, based on the structure of the C-code rather than on its compiled byte code, revealed a single condition-guarded path to two critical routines. The first routine checks the stability of the system clock for 500ms, setting the variable `magic` (a 16-bit register) to a specific value if there is no evidence of interference on the clock [2]. The second routine then generates a series of pulses to the detonator interface, periodically checking that interference has not changed the value of `magic`, and aborting if it has. It is estimated that 500ms of such pulses are sufficient to activate a detonator.

Two interference scenarios are considered. In the first, a single interference spike occurs with probability p_d while the system is running, and registers change with probability p_r when a spike occurs. Based on hardware and control logic considerations, it is shown that the probability of an unintended firing sequence is then approximately $p_d.p_r^2 \times 10^{-8}$, subject to a recommended code revision to introduce an extra conditional statement before executing the firing sequence. Under the assumption that $p_d = 1$, this leads to the conclusion that the highest IEC 61508 safety integrity level (SIL 4) is attained if $p_r = 0.1$, and SIL 3 is attained if $p_r = 1$.

Under the second scenario, a burst of N spikes of frequency f occurs. In this case, the probability of an unintended firing sequence is shown to be approximately $1-(1-1.86p_r^2(1-p_r)^{2m} \times 10^{-9})^N$, where m is the number of spikes that occur during an interval of 500ms. Under worst case assumptions (the burst endures for an hour and $p_r = \frac{2}{(f+2)}$) SIL 4 is attained when $f = 14kHz$, and far exceeded when f is in the range 150kHz–80MHz that is recommended in SANS 1717-1 (the relevant standard prescribed by the South African Bureau of Standards).

The study provides high confidence in the safety integrity of the system, especially since no interference has been observed, suggesting that in practice p_d and p_r are very low.

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[1] The companies are Anglo Platinum and Sasol Nitro. The latter commercialised and now markets this centralised blasting system under the name *SafeBlast*. The system allows for user-specified timed activation of detonators, leading to so-called timed explosions.

[2] The routine was prompted by a prior simulation exercise in which an unintentional firing sequence was generated on an earlier version. The misfiring could not be regenerated on the upgraded system.

Prediction and error propagation for geophysical fluids

Authors:

François-Xavier Le Dimet [a]

V. Shutyaev [b] I. Gejadze [c]

Predicting the evolution of geophysical fluids (ocean or atmosphere) has a great societal impact and therefore it's important to improve at best the prediction. But it makes sense only if we are able to product an information on the quality and fiability of the prediction.

There are many types of errors: error on the model because it is an approximation of the true fluids, error on the observations and also error on the past prediction. In the algorithm of data asimilation these errors are mixed and produce an error on the retrieved initial condition that will be propagated to the prediction.

Based on the theory of Optimal Control for partial differential equations, the variational approach for the assimilation of data gather all the available information in the so-called Optimality System (O.S.) which is the Euler-Lagrange equation of the optimization problem. Errors can be injected in the O.S. and we will be able to follow the propagation of the errors thanks to the Second Order Adjoint.

In the talk we will establish a relation between the Hessiian of the cost function applied to the error on the optimal initial condition and the error of model and the error of observation. We will see how to estimate the covariance of the initial condition and to have an efficient choice of perturbations for "ensemble" prediction.

A numerical example will be shown with an advection-diffusion type equation in the cases when advection (i.e. non linear processes) dominates and when diffusion (i.e. linear processes) dominates.

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"Grand" systèmes d'équations différentielles pouvant représenter un écosystème microbien

Authors:

Claude LOBRY [a]

Un bioréacteur destiné à la dépollution contient plusieurs milliers de populations d'espèces différentes, chacune comportant de l'ordre de 10^9 à 10^{12} individus. Un modèle possible pour l'évolution d'un tel écosystème est le système d'équations différentielles :

$$\begin{cases} \dfrac{ds}{dt} &= d(\varepsilon t)(Sin - s) - \sum_{i=1}^{N} \mu_i(s) x_i \\ \\ \dfrac{dx_i}{dt} &= (\mu_i(s) - d(\varepsilon t))x_i + \sigma\{\sum_{j=1}^{N} \alpha_{ij}\mu_j(s)x_j - \mu_i(s)x_i\} \quad i = 1, 2, ..., N \end{cases}$$

où :

- $x_i(t)$ est la concentration de l'espèce i à l'instant t,
- $s(t)$ est la concentration du substrat nutritif à l'instant t,
- $\mu_i(s)$ est une fonction de "type Monod" qui représente le taux de croissance de l'espèce i,
- α_{ij} est le taux de mutation de l'espèce j vers l'espèce i,
- d est le débit du flux qui traverse le réacteur.

Dans ces équations, N, le nombre d'espèces, est "grand" et les paramètres ε et σ sont petits. On montrera des simulations (pour $N = 100, 500, 1000$) qui présenteront des phénomènes curieux dont l'explication passe en partie par l'étude des petites dimensions ($N = 2$ ou 3).

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An inverse problem in physical geodesy

Authors:

Maher Moakher [a] Amine Abdelmoula [a] Bernard Philippe [b]

A problem of great importance in physical geodesy consists in finding the positions and intensities of point masses buried inside the earth for which the associated gravitational potential approximates a given potential field. When the given gravitational potential is to be approximated on the whole earth, the buried point-mass parameters are determined by solving an inverse problem which is formulated by expressing the two potentials in the spherical harmonics basis.

However, when only a limited region of the earth is considered, the spherical harmonics basis is no longer orthogonal and consequently the spherical harmonic basis is not appropriate for the local problem. We therefore construct a Slepian basis of functions whose energies are concentrated in the considered region. The inverse problem is then formulated as a minimization problem for the determination of the point-mass parameters by expressing the given potential and the equivalent one in terms of the Slepian basis functions. A Newton-like method is developed for the numerical solution of this minimization problem.

Numerical examples are presented for the identifiability and stability questions of the this inverse problem.

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A fourth-order discontinuous Galerkin scheme for the elastodynamic equations

Authors:

Serge Moto Mpong [a]

Nathalie Glinsky-Olivier [b] Stéphane Lantéri [c]

In this paper, we introduce and analyse a fourth-order leap-frog scheme in time, coupled with a centered discontinuous Galerkin approximation in space, for the solution of the elastodynamic equations. The time discretization is obtained via a simple construction based on Taylor developments. It provides us an accurate and non dissipative scheme for the numerical simulation of seismic wave propagation. Numerical results of the homogeneous eigenmode problem are presented in order to study numerical stability and numerical convergence of this method both for regular and unstructured meshes. This numerical study confirms the theoretical order of convergence of the scheme and the suitability of the method to deal with unstructured meshes.

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FVCA5 Benchmark: results on numerical schemes for anisotropic diffusion problems on general grids

Authors:

Ibrahim Moukouop Nguena [a] Abdou Njifenjou [a]

Following the spirit of the FVCA5 Benchmark, we present some powerful numerical schemes designed for numerical simulation of anisotropic diffusion phenomena in heterogeneous media. Details can be found in [1, 2].

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Approximation of blowing up solutions to semilinear parabolic equations

Authors:

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We consider the problem of finding $\{T_b, u\}$, $0 < T_b \leq \infty, u : \overline{\Omega} \times [0, T_b)$ such that:

$$u_t = \Delta u + \lambda f(u), x \in \Omega, 0 < t < T_b,\ u(x,0) = u_0(x) \geq 0, \forall\, x \in \Omega$$

Typical cases for the function f are $f(u) = e^u$, $f(u) = u^p$, $p > 1$. We consider the problem of stable computation to an inherently unstable problem and use a method of perturbations using systems with "mass conservation". For ϵ "small" positive number, we consider the system of finding $\{u^\epsilon, v^\epsilon\} : \overline{\Omega} \times [0, \infty) \to \mathbb{R}^2$ such that:

$$u^\epsilon_t - \Delta u^\epsilon = f(u^\epsilon)v^\epsilon,\ v^\epsilon_t - \Delta v^\epsilon = -\epsilon f(u^\epsilon)v^\epsilon, x \in \Omega,\ t < \infty,$$

$$u^\epsilon(x,0) = u_0(x) \geq 0; v^\epsilon(x,0) = 1, x \in \Omega,\ u^\epsilon(x,t) = 0; v^\epsilon(x,t) = 1, x \in \Gamma, t < \infty.$$

$\epsilon = 0$ in gives as a limit case the solution u of the original system. We prove the following estimates on $\{u_\epsilon, v_\epsilon\}$:

$$||u - u^\epsilon||_\infty(t) \leq C_{R_T}\epsilon,\ ||1 - v^\epsilon||_\infty \leq c_{R_T}\epsilon.$$

$$C_{R_T} = c_0[f(R_T)]^2 T_b^2 e^{f'(R_T)T_b},\ c_{R_T} = c_0 f(R_T)T_b.$$

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Computation of monotone linear threshold functions by monotone boolean formula

Authors:

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Jacques Mazoyer [a] Maurice Tchuente [b]

We show that there exists a monotone linear threshold function on N Boolean variables that can't be exactly computed by a polynomial size monotone Boolean formula. This implies that there exists a monotone weighted threshold function on N Boolean variables that can't be simulated by a monotone constant depth polynomial size circuit of majority gates.

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Convergence analysis on square meshes of a DDFV type method for flow models in porous media

Authors:

Abdou Njifenjou [a] A. J. Kinfack [a,b]

The aim of this paper is to present the theoretical analysis of a Discrete Duality Finite Volume (DDFV) solution to flow problems in anisotropic heterogeneous media with various boundary conditions. We start with the derivation of the discrete problems associated respectively with Dirichlet and Neumann boundary conditions. Then we give a result of existence and uniqueness for a solution to each of these two discrete problems. The main results to exhibit in this paper is the convergence analysis of P_1-, Q_1- and $Q_2 - finite\,volume$ solutions introduced in our previous works. This result is strongly based upon the concepts of weak and weak-star DDFV approximate solutions also introduced in our earlier works. Their theoretical properties, namely stability and error estimates (in discrete energy norms, $L^2 - norm$ and $L^\infty - norm$), have been investigated. These properties play a key role in the analysis of P_1-, Q_1- and $Q_2 - finite\,volume$ solutions mentioned above.

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Numerical methods for the solution of a problem in fluid mechanics

Authors:

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Most physical problems are naturally formulated as boundary value problems in domains with three space variables. But three-dimensional computations are very expensive and sometimes quite impossible with today's techniques, due to the number of unknowns and the complexity of the partial differential equation. The geometry of the domain is also a source of algorithmic complexity due to the representation of the surface and the mesh design inside the domain. So it is worthwhile to reduce the problem to two-dimensional equations. Stokes problem which governs the flow of incompressible viscous fluids is one of these problems. By using the cylindrical coordinates and considering the case of axi-symmetric data, that is where none of the data depends on θ, this problem leads to two simpler problems namely a saddle point one and another elliptic one [1, 3]. Details for decoupling techniques can be found in [2, 4].

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Comparison of some linear solvers on systems arising from fluid dynamics

Authors:

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Nowadays, there are several libraries for solving large sparse unsymmetric linear systems. They include sequential and parallel solvers with supernodal and multifrontal direct methods, multigrid and multilevel iterative solvers. In this presentation, we will give some results with some of these packages on systems arising from fluid dynamics. We will show that parallel direct methods are not suitable for all of these systems. For instance, it seems that static pivoting used in SuperLU_DIST [2] does not achieve good accuracy in the final solution with some matrices. In the case of iterative solvers, existing parallel preconditioners are efficient under some limits in the size of systems being solved. Then we will introduce a new package including parallel multiplicative shwarz preconditioner for GMRES named as GPREMS [1].

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Construction of bases of Krylov subspaces of moderate condition numbers

Authors:

B. Philippe [a]

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This talk discusses the Arnoldi process, which constructs orthogonal bases of Krylov subspaces. These spaces are of utmost importance in linear algebra involving operators in finite- but high-dimensional spaces. We modify the standard algorithm in order to obtain an implementation suited for parallel computation. Specifically, we would like to avoid the computation of many inner products of distributed vectors in order to achieve scalability.

Given a large matrix $A \in \mathbb{R}^{n\times n}$ and a vector $b \in \mathbb{R}^n$, the Krylov subspaces $\mathcal{K}_k(A,b) = \mathcal{P}_{k-1}(A)b$, $k = 1, 2, \dots$, are used to i) solve the linear system of equation $Ax = b$, ii) compute a few desired eigenvalues of A, and iii) compute an approximation of $f(A)b$, where f is an analytic function. These computations can be carried out recursively.

The Krylov subspace $\mathcal{K}_k(A,b)$ is spanned by the canonical basis $\{b, Ab, A^2b, \cdots, A^{k-1}b\}$. However, this basis is numerically useless. The well-known Arnoldi process generates recursively an orthonormal basis of $\mathcal{K}_k(A,b)$, using the Modified Gram-Schmidt process. Unfortunately, the latter relies heavily on inner product evaluations, which are difficult to evaluate efficiently in a parallel computing environment. Our remedy is to first determine a nonorthogonal, but not too ill-conditioned, basis of $\mathcal{K}_k(A,b)$, and then to orthogonalize this basis with an efficient parallel algorithm.

We first review an approach described in [1] and applied in [2, 3, 4]. A few numerical examples and variations of this approach will be discussed. In the second part of the talk, we consider the construction of a basis with orthogonal polynomials by investigating the Chebyshev case. This ongoing work follows a research topic, which received considerable attention more than 15 years ago in an another context.

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Modeling Hepatitis B

Authors:

Gauthier Sallet [a]

We present the natural history of the infection with HBV. We analyse some models of the literature and present some new models.

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Competition in the chemostat with a slowly varying washout rate

Authors:

Tewfik Sari [a,d] Claude Lobry [b,d] A. Rapaport [c,d]

We study a model with two competitors competing for a single nutrient in a chemostat with a slowly varying washout rate. We show that the model exhibits the delayed loss of stability phenomenon when the washout rate crosses the bifurcation value at which the growth curves of the two competitors intersect. Details can be found in [1].

The mathematical model is

$$\begin{aligned} s' &= D(s_{in} - s) - \mu_1(s)x_1 - \mu_2(s)x_2 \\ x_i' &= (\mu_i(s) - D)x_i, \qquad (i = 1, 2) \end{aligned}$$

where $x_1(\cdot)$ and $x_2(\cdot)$ are the concentrations of the two different micro-organisms. The growth functions $\mu_i(\cdot)$ are assumed to be strictly monotonic and such that $\mu_i(0) = 0$. The term D is called the *washout rate*. We denote by λ_i the break-even concentrations $\mu_i^{-1}(D)$. When D is kept constant, it is well known from the Competitive Exclusion Principle (CEP) that generically at most one competitor survives asymptotically : when $\lambda_1 < \lambda_2$, the CEP claims that the equilibrium $(\lambda_1, s_{in} - \lambda_1, 0)$ is globally asymptotically stable (see [2]).

We consider growth curves μ_1 and μ_2 that intersect in exactly one point $s^* > 0$: $\mu_1(s^*) = \mu_2(s^*) = D^* < s_{in}$ with $\mu_2(s) < \mu_1(s)$ for $0 < s < s^*$ and $\mu_2(s) > \mu_1(s)$. Furthermore, we consider a slowly varying washout rate $D = D(\varepsilon t)$, that is $\varepsilon > 0$ is small, that alternatively favors competitor 1 and competitor 2.

In natural ecosystems, such as in mountain lakes for instance, one may expect that the variations of the environment are much slower than the biological time scale. We focus here on the transient behavior of the dynamics, and show that when D crosses the bifurcation value D^* i.e. gets more favorable to the other species, one may have to wait a large time before observing the density of this later species becoming dominant. This phenomenon is known in slow-fast dynamics as a stability loss delay. Here, we provide also an approximation of this delay.

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Computation of the Mittag-Leffer matrix function that arises in fractional differential equations

Authors:

Roger Blaise Sidjé [a] Kevin Burrage [b,c]

Although not as commonly encountered as other special functions, the Mittag-Leffer function, which is a generalization of the exponential function, arises when modeling certain physical and biological processes with anomalous diffusion. Such processes are formulated in terms of derivatives (and integrals) of fractional (non-integer) order. The aim is to investigate numerical methods for computing the Mittag-Leffer function, defined as

$$E_\alpha(z) = \sum_{k=0}^{\infty} \frac{z^k}{\Gamma(\alpha k + 1)}, \quad 0 < \alpha < 1, \quad z \in \mathbb{C}, \tag{1}$$

or more generally

$$E_{\alpha,\beta}(z) = \sum_{k=0}^{\infty} \frac{z^k}{\Gamma(\alpha k + \beta)}, \quad \alpha \in \mathbb{R}^+, \quad \beta \in \mathbb{R}, \quad z \in \mathbb{C}. \tag{2}$$

Our focus will be (1) in which the argument is actually a matrix, possibly of large dimension. Evaluating the matrix counterpart is an added challenge and is compounded with the fact that even the scalar evaluation is not yet as well established as other special functions. This is evidenced by the fact that popular commercial problem solving environments (such as Matlab, Maple or Mathematica) do not have a built-in Mittag-Leffer function.

In the particular case where $\alpha = 1$, since $\Gamma(k+1) = k!$, (1) reduces to the usual exponential function. Despite this close connection, most of the techniques used for the exponential are not directly applicable to the Mittag-Leffer function because algorithms to efficiently evaluate the exponential rely on two properties that are not satisfied by the Mittag-Leffer function, namely the *separability* property $e^{x+y} = e^x e^y$, and the *exponentiation* property $e^{nx} = (e^x)^n$. In the C/C++ language for example, the intrinsic function for e^x is based on the decomposition $x = k \ln 2 + r$, where $|r| \leq \frac{1}{2} \ln 2 \approx 0.34658$, which then gives $e^x = 2^k e^r$, with e^r evaluated using a rational function based on an approximation polynomial of degree 5 generated by a special Remes algorithm on $[0, 0.34658]$ with a maximum error bound of 2^{-59} in IEEE arithmetic (see `netlib.org/fdlibm/e_exp.c` for details). This illustrates how the particular properties of the exponential function have *enabled* the design of very efficient and accurate algorithms, yet these do not directly translate to the Mittag-Leffer function, and this motivates our own interest to the problem. At the same time it is seen from the underlying subtleties that a degree of sophistication is neded to produce quality numerical algorithms that applications can confidently rely upon.

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Existence locale et régularité de solutions de problèmes intégro-différentiels à retard infini dans les espaces de Banach

Authors:
Hamidou Touré [a]

Nous présentons dans cette communication des résultats d'existence et de régularité de problèmes intégro-différentiels avec retard infini dans des espaces de Banach. Nous faisons l'hypothèse que la partie sans retard admet un operateur résolvant au sens de Grimmer. La partie soumise à l'effet retard est supposé localement Lipchitzienne. Nous établissons dans un premier temps l'existence de solutions au sens de la théorie des semi-groupes linéaires. Nous donnons ensuite des conditions nécessaires qui assurent l'existence de solutions strictes (régulières).

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Le modèle Ross Macdonald pour des environnements hétérogènes avec migrations entre zones

Authors:

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Berge Tsanou [a,d]

Nous étudions l'extension du modèle proposé par Ross Macdonald pour le paludisme, aux environnements hétérogènes constitués de plusieurs zones géographiques avec des migrations de populations hôtes entre zones, mais sans migration de moustiques. Dans le cas particulier où les coefficients de migration ne dépendent pas du statut épidémiologique des hôtes, une étude précédente avait permis de calculer le taux de reproduction de base R_0, et de démontrer la stabilité globale des points d'équilibre. Nous donnons ici une formulation explicite pour R_0, dans le cas où les migrations sont rapides avec en plus des coefficients qui varient d'un compartiment épidémiologique à l'autre. Nous montrons que si $R_0 < 1$, alors le point d'équilibre est globalement asymptotiquement stable. Des simulations numériques sont ensuite présentées pour le cas $R_0 > 1$ ainsi que pour les systèmes correspondant aux migrations lentes.

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Image retrieval on the Grid using vector space model

Authors:

Marian Vajteršic [a] T. Berka [a] R. Kutil [a]

There are many reasonable arguments to adopt parallel computing on the grid [1] as a paradigm for computationally intensive tasks, such as retrieval in large image databases. However, communication on the grid suffers from costly web-services. In this contribution, we present a bulk synchronous parallel approach for the reduction of these overheads.

By partitioning features and documents we operate on a block partitioned corpus matrix. We organize our hosts as a 2D mesh, such that each host holds and indexes only a single block. Previous work suggests that a suitable partitioning can provide a reduction of complexity at only a small decrease or ideally even an increase of retrieval accuracy [3]. Unfortunately, our experiments with image test sets indicate that the dense, relatively low dimensional vectors involved are not well suited for a strong rank reduction of the SVD, for which efficient parallel methods have recently been developed [2].

The initiation of tasks, distribution of queries and combination of local results is realized using a *virtual* communication structure of a binary tree. We execute local operations at one of the two sending hosts instead of involving a third node, cutting the data volume sent by 50%. For improved communication parallelism, we apply this hierarchical scheme recursively within rows and columns of hosts, allowing us to reach all hosts in logarithmic complexity.

The same communication mechanism can also be used to build feature statistics across the entire collection to improve the retrieval performance through feature weighting.

The theoretic speedup without communication cost, assuming a balanced distribution of features and documents, is linear in the number of hosts. The actual performance is based on the cost of communication and the balance of the distribution of entities.

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