Master Thesis in Numerical Analysis
6 Proposals for the summer 2009
Summary

1) ***Multidimensional Advection Schemes For Multi-Species Transport In Porous Environment***

Anthony Michel, anthony.michel@ifp.fr
Quang Huy Tran, q-huy.tran@ifp.fr

Theme : Numerical analysis, implementation in an industrial code.
Prerequisites : numerical analysis (approximation of hyperbolic equations by finite differences and finite volumes and programming (C++, LATEX).
Remuneration : 770 e/month (gross).
Duration : 4 to 6 months
Address: IFP, Department Mathematical Applied, 1 and 4 avenue de Bois Préau, 92852 Rueil - Malmaison Cedex, France.

2) ***Newton's Or Non-Linear Conjugate Gradient Methods For Reactive Transport Problems***

Nikos Leterrier *nikos.leterrier@cea.fr*

Theme : Numerical analysis,fluid mechanics.
Prerequisites : numerical analysis (finite differences, finite volumes, Newton method) and programming (C++ or Fortran, LATEX).
Remuneration : 700 euros/month gross (around 550 euros/month net), possible accomodation allowance around 220 euros/month and a bonus at the end of the internship
Duration : 6 months
Address: CEA (Commissariat à l'Energie atomique), **91191 Gif sur Yvette Cedex**.

3) ***Study of Capillary Equilibrium Surfaces***

Samuel KOKH1 (samuel.kokh@cea.fr)

Theme : Minimal surfaces.
Prerequisites : Calcul of variations, possibly some programming.
Remuneration : 700 euros/month gross (around 550 euros/month net), possible accomodation allowance around 220 euros/month and a bonus at the end of the internship
Duration : 6 months
Address: CEA (Commissariat à l'Energie atomique), **91191 Gif sur Yvette Cedex**

4) ***Analysis And Development Of A Non-Linear Iterative Method Based On The Two-Step Transport- diffusion Scheme For Nuclear Reactor Core Calculations.***

Jean Michel Do, jean-michel.do@cea.fr
Emiliano Masiello, emiliano.masiello@cea.fr

Theme : Transport solver, numerical methods.
Prerequisites : Advanced numerical analysis, Fortran 90 strictly demanded.

Remuneration : 700 euros/month gross (around 550 euros/month net), possible accomodation allowance around 220 euros/month and a bonus at the end of the internship
Duration : 6 months
Address: DEN/DANS/DM2S/SERMA/LTSD, **CEA Saclay 91191 Gif sur Yvette Cedex**

5) ***Homogeneization And Local Defects***

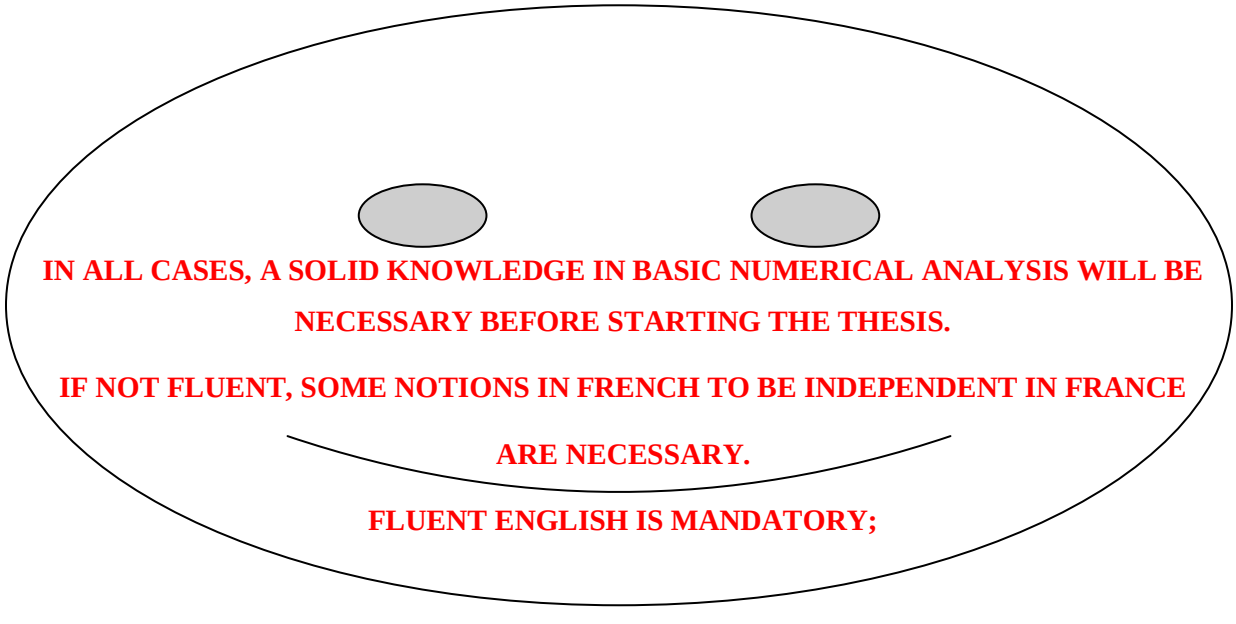
Jean Jacques Marigo - marigo@lmm.jussieu.fr

Theme : Mechanics, Matched asymptotic expansions
Prerequisites : Solid Mechanics: Elasticity, variational methods, asymptotic expansions.
Remuneration : 550 euros/month .
Duration : 4 to 6 months
Address: Jean Jacques Marigo - Laboratoire Jean Le Rond d'Alembert, Université Paris 6, 4 Place Jussieu, Paris 75005.

6) ***Numerical Methods for solving parabolic PDE arising in quantitative finance in dimension larger than 2***

Alain Galli (ENSMP) Alain.Galli@ensmp.fr
L. Halpern

Theme : financial mathematics, parabolic PDE's.
Prerequisites : probabilities, numerical schemes for PDE's, Monte-Carlo methods , matlab.
Remuneration : *570 euros/month + round trip ticket.*
Duration : 3 to 4 months
Address: Ecole des Mines, 60 Bd Saint-Michel , 75005 Paris-



Multidimensional advection schemes for multi-species transport in porous environment

Anthony Michel* Quang Huy Tran*

The object of this training course is to study a new class of schemes of multidimensional advection, within the framework of multi-species transport in porous environment. By advection scheme is meant a numerical approximation of the solution $(T, X) \rightarrow \varphi(T, X)$ of the equation

$$\partial_t \varphi + U \cdot \nabla_x \varphi = 0 \qquad (1)$$

where U is a given velocity field.

Whereas numerical methods for the one dimensional advection are for the majority very powerful, rare are those that give whole satisfaction when extended to multidimensional scheme, in particular when the grid is strongly deformed. In spite of the efforts made by researchers and the abundance of existing methods, the search of an ideal one still remains open.

We wish to examine VOFIRE type scheme , initially proposed by Després-Plowed-Lagoutière and to which we bring a certain number of substantial modifications. In addition to the theoretical aspects (stability and precision analysis), the question is also to know in which situations these modifications bring systematic improvement. New and promising, these schemes are by construction well integrated in industrial application code.

Developments could be done within the Arcane platform which already includes some basic advection schemes . This would facilitate the comparison tests .

This work will proceed on the site of Rueil-Malmaison. It requires knowledge in numerical analysis (approximation of hyperbolic equations by finite differences and finite volumes and programming (C++ computer programming language, LATEX). Remuneration is about 770 e/month (gross).

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Proposal for a trainee position in the French Nuclear Agency (CEA) in the Laboratory for Flow and Transport Simulation for a student finishing the master's degree

Domain : Numerical analysis
Duration : 6 months
Place : CEA-Saclay (parisian region, France)
Language: French or English or German
Contact : nikos.leterrier@cea.fr

Financial conditions: 700 euros/month gross (around 550 euros/month net), possible accomodation allowance around 220 euros/month and a bonus at the end of the internship.

We aim to test numerically a method for the analytical evaluation of the jacobian within the frame of resolving a coupled reactive transport system through Newton's or Non-Linear Conjugate Gradient methods. Reactive transport problems appear in many industrial areas such as the pollution studies or underground storage of nuclear waste, the latter being of interest here.

When chemical reactions are taken at thermodynamic equilibrium, it is impossible to write explicitly the chemical source terms in the reactive species' equations of evolution. It is fairly common to use an operator-splitting technique for sequential approaches and the direct substitution for a global approach. In both cases the jacobian is very often evaluated through a numerical approximation.

We aim here to evaluate the jacobian through an analytic calculation, using the mathematical properties of the chemical system (action mass laws), in the mainframe of a global approach, but without direct substitution. This analytical calculation is possible although the analytical expression of the function whose jacobian is calculated is unavailable.

The work will consist in proposing reactive transport tests in order to test this new method, and to compare the results with the numerical evaluation of the jacobian, and another analytical evaluation of the jacobian in the mainframe of the direct substitution approach. The accuracy of results and performances should be taken into account for this comparison. The trainee will be left free to choose the numerical tool for programmation: it can be C, C++ , Fortran etc…

Study of Capillary Equilibrium Surfaces

Master Thesis Proposal

Location : CEA Saclay

Advisor : Samuel KOKH[1] (samuel.kokh@cea.fr)

Duration : 4 to 6 months

Financial conditions : 700 euros/month gross (around 550 euros/month net), possible accomodation allowance around 220 euros/month and a bonus at the end of the internship.

We propose through this Master Thesis subject a rough review of some problems related to the surface Γ that separates two fluids at mechanical equilibrium. Both fluids are supposed in thermal equilibrium and we shall only take capillary effects, gravity and the influence of solid boundaries into account.

The dimension of the ambient space is (d+1), and we consider both fluids to be enclosed within a portion of space delimited by $\Omega \times I$, where Ω is a bounded open subset of $\mathbb{R}^d$ and I is an open set of $\mathbb{R}$.

1 The Minimal Surface Problem

A first historical approach to this problem has led to a pure geometrical called the Minimal Surface Problem. This problem consist in determining Γ as a curve with a minimal mean curvature under additional constraints prescribed by the physical context (gravity, solid boundaries for example). If one seek Γ as the graph of a fonction $u : \Omega \to \mathbb{R}$, then u is meant to verify the following famous variational problem:

$$J(u) = \min_{v \in \mathrm{BV}(\Omega)} J(v), \text{ where} \tag{1}$$

$$J : v \in \mathrm{BV}(\Omega) \mapsto \int_\Omega \frac{\mathrm{d}x}{\sqrt{1+|\nabla u|^2}} + \frac{\kappa}{2}\int_\Omega v^2 \mathrm{d}x + \int_{\partial\Omega} \beta v \mathrm{d}\gamma, \tag{2}$$

with $\kappa \in \mathbb{R}_+$, and $\beta : \partial\Omega \to \mathbb{R}$ such that $\beta \leq 1$. If u is a regular solution of (1)-(2), then u is also a solution of the well-known problem:

$$-\mathrm{div}\left(\frac{\nabla u}{\sqrt{1+|\nabla u|^2}}\right) + \kappa u = 0 \quad \text{in } \Omega, \tag{3}$$

$$-\frac{\mathbf{n}\cdot\nabla u}{\sqrt{1+|\nabla u|^2}} = \beta \quad \text{on } \partial\Omega, \tag{4}$$

[1] DEN/DANS/DM2S/SFME/LETR, CEA Saclay, Gif sur Yvette CEDEX, France.

where $\mathbf{n}$ is the outter unit normal to Ω.

We propose to elaborate a short review of such problems using two articles. The first one [2] considers a simplified symmetric problem and seek for the solution as the stationnary state of an evolutionnary equation. The second article [1] examines the general cases with additional constraints such as a volume constraint on one of the fluid. This article also refers to a serie of other paper by the same author about the same topic.

The student is not intended to acquire an exhaustive knowledge of this famous problem, but she/he should be able to grasp essential notions related to it. Both article shall be considered as initial lead.

2 Diffuse Interface Modelling

The following work is considered as a complementary work to bibliographical task of the first section. An alernative to the surface minimal problem consist in considering the interface that separates both fluids as non-zero thick transition zone. Such approach is referred as diffused interface models and is often used in Computational Physics. We also propose to examine the possible connection between a diffuse interface model at equilibrium and the minimal surface problem. One may for example consider the case of a simple 2D bubble at equilibrium with its surrounding neglecting gravity effects and try to recover the Laplace equation that connects the pressure jump across the material interface and the curvature of the bubble.

We propose for such problem to examine stationnary solutions of an isothermal Euler-type model such as

$$\partial_t \rho + \mathrm{div}(\rho \mathbf{u}) = 0, \tag{5}$$

$$\partial_t(\rho \mathbf{u}) + \mathrm{div}(\rho \mathbf{u} \times \mathbf{u} + (P - \sigma|\nabla\alpha|^2/2)\mathrm{Id} + \sigma \nabla\alpha \otimes \alpha) = \rho \mathbf{g}, \tag{6}$$

$$\partial_t \alpha + u \cdot \nabla \alpha = 0, \tag{7}$$

where α is a smooth function valued in $[0, 1]$ such that $\alpha = 1$ (resp. 0) in fluid 1 (resp. 0).

3 Numerical Tests

The following is also considered as a complementary work. The student may also perform numerical simulations using programming tools of her/his choice (C/Fortran/Matlab/Scilab/Python...) in order to compute equilibrium capillary surfaces. This may involve minimal surfaces computation or the simulation of diffuse interface models.

References

[1] C. GERHARDT. *A Free Boundary Valued Problem for Capillary Surfaces*, Pacific Journal of Math., vol. 88, No. 2, 1980.

[2] N. ISHIMURA. *Existence of Symmetric Capillary Surfaces via Curvature Evolution*, J. Fac. Sci. Univ. Tokyo. Sect. IA, Math., No. 40, 1993.

INTERNSHIP PROPOSITION FOR 2009

Laboratory: DEN/DANS/DM2S/SERMA/LTSD
(Laboratoire de Transport Stochastique et Déterministe)
Director: Sylvie Naury
Address: CEA de Saclay 91191 Gif sur Yvette Cedex

Tutors: Jean Michel Do, Emiliano Masiello
Telephone: +33.(0)1.69.08.27.44, +33.(0)1.69.08.86.09,
Fax: +33.(0)11.69.08.94.90
Email: jean-michel.do@cea.fr , emiliano.masiello@cea.fr

Duration: 4 to 6 months (starting approximatively in April)

Financial conditions: 700 euros/month gross (around 550 euros/month net), possible accomodation allowance around 220 euros/month and a bonus at the end of the internship.

internship Title:
Analysis and development of a non-linear iterative method based on the two-step transport-diffusion scheme for nuclear reactor core calculations.

Subject Description:
The calculation scheme for nuclear reactor cores is based on a two-step physical modeling; the first modeling is at the assembly scale while the second is at the core scale. The neutron flux in a fuel assembly is analyzed in an ideal infinite network of the same assembly by numerically solving the transport equation. The energy mesh, the angular mesh and the spatial mesh for the assembly flux must be very detailed. Indeed such a flux will provide the neutron spectrum necessary for the homogenization in space and the condensation in energy. This process builds-up the few-group homogenized cross-sections for the assembly that feed the core modelization. At the core scale, the calculation is performed using a coarse energy mesh (2 or 4 groups) and by considering each assembly as a homogeneous material.
Because of the infinite lattice approximation, the transport calculation introduces inevitably errors in the homogenization process. These errors are very difficult to monitor and control. In this internship, a new two-step scheme is proposed: the non-linear transport-diffusion equivalence is calculated iteratively to take into account the interface effects at the boundary of each assembly. The iterative process will be initiated by an infinite lattice calculation.

Then, a coarse operator (coarse in space, in energy and in angle) will be built dynamically during iteration across the core by utilizing a transport-diffusion equivalence based on the conservation of the neutron balance. This calculation will provide the entering current in each assembly and the k-effective of the core to reiterate a new transport calculation at the assembly scale. This process will take into account the real boundary conditions for assemblies.
The candidate will work with the IDT transport solver that solves the transport equation in XYZ geometry using the discrete ordinates approximation for the angular variable and the methods of short characteristics or nodal for the spatial variable.
A deep knowledge of the Fortran90 language programming is strictly demanded.

Homogeneization and local defects.

Jean Jacques Marigo - Laboratoire Jean Le Rond d'Alembert
marigo@lmm.jussieu.fr
Université Paris 6
4 Place Jussieu
Paris 75005

Duration : 4 to 6 months

Financial conditions : around 550 euros/month net

THe aim of this Master's thesis is to get acquainted with matched asymptotic developments.

After studying the method on simple cases, the student will apply it to a more realistic problem.
This will be the case of a 2D elastic structure with strengtheners included along a structural curve
and periodically distributed.

The goal is to determine the influence of these strengtheners on the global behaviour of the structure.

Theoretical analysis will be coupled with numerical computations using Finite Element software.

Prerequisites:
Solid Mechanics: Elasticity

Mathematics: Variational Methods.

A Phd can follow this Masters Thesis

Le but du stage de master est de se familiariser avec la méthode des développements asymptotiques raccordés.
Après l'avoir étudié sur des exemples simples, l'étudiant l'appliquera à une situation plus réaliste. Il s'agira d'une structure 2D élastiques contenant des renforts de type inclusionnaires centrés sur une courbe de la structure et répartis périodiquement le long de celle-ci.

L'objectif est de déterminer l'influence de ces renforts sur le comportement global de la structure. Cette étude théorique s'accompagnera de calculs numériques utilisant des logiciels d'éléments finis.

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Ce stage peut déboucher sur une thèse

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Internship proposal

Subject : Numerical Methods for solving parabolic PDE arising in quantitative finance in dimension larger than 2

Advisors: Alain Galli (ENSMP) and L. Halpern (Univ. Paris 13)

Location Ecole des Mines de Paris

60, Boulevard Saint Michel, Paris

Project topic

Under the complete market hypothesis most derivatives used in finance like European options on equity or fixed income can be evaluated in two different ways, either by computing a conditional expectaction or solving a parabolic PDE. The latter method is known to be faster than the first in spaces of dimension up to two. However more and more complex products have to be evaluated leading to higher dimensional spaces.

Here we wish to investigate two types of methods which are less sensitive to the curse of dimensionality:

1. Hybrid methods coupling Monte Carlo Simulations & PDE numerical methods
2. Using adaptive spatial tensor product wavelet to represent the solution.

The work will start with a thorough literature search on the two methods, then applications to test problems coming to finance will be developed, in order to determine the performance of the methods in practice.

Conditions

Location: The intern will be based at the Ecole des Mines, 60 Bd Saint-Michel in central Paris.

Duration: 3 to 4 months

The intern will receive

- An economy class electronic return ticket Ho-Chi-Minh Ville-Paris will be sent to the intern,
- A monthly stipend of 750 euros.

Some help will be provided in finding accommodation.