Sesión *Análisis Numérico de Ecuaciones Diferenciales Parciales*
Encuentro anual 2017 de la Sociedad de Matemática de Chile

Las charlas son de 25 minutos, más 5 minutos de preguntas.

Jueves 2 de Noviembre, 17:40 – 19:10

- 17:40 – 18:10 **Abner Poza**, Universidad Católica de la Santísima Concepción
  A stabilised finite element method for the convection–diffusion–reaction equation in mixed form
- 18:10 – 18:40 **Bryan Gomez**, Universidad de Concepción
  Mixed-primal finite element methods for stress-assisted diffusion problems
- 18:40 – 19:10 **Esteban Cortes**, Universidad Técnica Federico Santa María
  Análisis de error a posteriori para problemas temporales mediante esquemas estabilizados de elementos finitos

Viernes, 3 de Noviembre, 11:10 – 12:40

- 11:10 – 11:40 **Norbert Heuer**, Pontificia Universidad Católica de Chile
  A DPG method for the Kirchhoff–Love plate bending model
- 11:40 – 12:10 **Francisco Fuica**, Universidad Técnica Federico Santa María
  Adaptive finite element methods for sparse PDE–constrained optimization
- 12:10 – 12:40 **Tomas Barrios**, Universidad Católica de la Santísima Concepción
  A-priori error estimate for a new DG approach applied to Laplace operator

Viernes, 3 de Noviembre, 15:40 – 17:10

- 15:40 – 16:10 **Mauricio Sepulveda**, Universidad de Concepción
  On exponential stability for thermoelastic plates – a comparison of different models
- 16:10 – 16:40 **Cesar Naranjo**, Universidad Técnica Federico Santa María
  Un método de elementos finitos estabilizados de bajo orden a divergencia nula para el problema de Boussinesq estacionario
- 16:40 – 17:10 **Ramiro Rebolledo**, Universidad de Concepción
  An a posteriori error estimator for the MHM method applied to Stokes/Brinkman equations

Sabado, 4 de Noviembre, 11:10 – 12:40

- 11:10 – 11:40 **Rommel Bustinza**, Universidad de Concepción
  An a posteriori error estimate for an augmented pseudostress-velocity mixed FEM formulation for a generalized Stokes problem
- 11:40 – 12:10 **Thomas Führer**, Pontificia Universidad Católica de Chile
  A linear Uzawa-type solver for nonlinear transmission problems
- 12:10 – 12:40 **Michael Karkulik**, Universidad Técnica Federico Santa María
  Variational formulation of time-fractional parabolic equations

LXXXVI Encuentro Anual. Talca 2017
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A-priori error estimate for a new DG approach applied to Laplace operator*

G. Barrenechea†, T. Barrios‡ and R. Bustinza§

Abstract

In this talk, we discuss the well posedness of a modified LDG scheme of the Poisson problem, considering a dual mixed formulation. The difficulty here relies on the fact that the application of classical Babuška-Brezzi theory is not easy for low order finite elements, so we proceed in a non-standard way. We first prove uniqueness, and then we apply a discrete version of Fredholm's alternative theorem to deduce existence, while the a priori error analysis is done by introducing suitable projections of exact solution. As a result, we prove that the method is convergent, and under suitable regularity assumptions on the exact solution, the optimal rate of convergence is guaranteed. As a particular case we comment our result applied to Darcy flow, where we can establish the well posedness for low order finite elements and the corresponding optimal rate of convergence is established with standard additional regularity assumption of the exact solution.

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An aposteriori error estimate for an augmented pseudostress-velocity mixed FEM formulation for a generalized Stokes problem*

Tomás P. Barrios[†], Rommel Bustinza[‡], Galina C. García[§], and María González[¶]

Abstract

We obtain a new a posteriori error estimator for a stabilized mixed method for the generalized Stokes problem. The stabilized scheme is obtained by adding suitable least squares terms to the dual mixed variational formulation associated to the generalized Stokes problem. Then, in order to approximate its solution using adaptivity of the meshes, we derive a reliable and local efficient a posteriori error estimator of residual type. Specifically, we develop an a posteriori error analysis based on the quasi-Helmholtz decomposition ([3]) which helps us to prove the so called local efficiency of the estimator with non-homogeneous boundary condition. Finally, we present some numerical examples that confirm the theoretical properties of our approach.

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Análisis de error a posteriori para problemas temporales mediante esquemas estabilizados de elementos finitos

Esteban Cortés Sandoval *

Resumen

Se desarrolla un análisis *a posteriori* para la ecuación de difusión-convección-reacción no estacionaria mediante esquemas estabilizados de elementos finitos. Dicho análisis se realiza en dos de las normas más usuales en términos de problemas espacio temporales, la norma asociada al espacio $L^2(0,T;H_0^1(\Omega))$ y la norma usual del espacio $\mathbb{W}(0,T)$, donde la principal diferencia entre ambas es que para el segundo caso la norma espacial corresponde a una norma aumentada que considera la norma dual de la derivada temporal. De esta manera se obtiene en ambos casos, cotas superiores e inferiores garantizadas a través de un estimador de error *a posteriori* completamente computable el cual se descompone en cuatro componentes: una referente al error inicial η_0, una al error espacial η_h^n, una al error temporal η_t^n y una al error de oscilacin η_D^n. Para lo cual se tiene que en ambos casos la cota superior es global en espacio y tiempo, es decir de manera general se tiene que

$$\|e\|^2_{\Omega\times(0,T)} \leq \eta_0^2 + \sum_{n=1}^{N}\left((\eta_h^n)^2 + (\eta_t^n)^2 + (\eta_D^n)^2\right),$$

mientras que la cota inferior es global en espacio y local en tiempo, es decir

$$(\eta_h^n)^2 + (\eta_t^n)^2 \leq C_1\,\|e\|^2_{\Omega\times(t^{n-1},t^n)} + C_2\,(\eta_D^n)^2.$$

La discretización del problema se hace a través del método de las líneas, haciendo uso de un esquema de Galerkin Estabilizado para la discretización de la variable espacial, considerando los esquemas de estabilización SUPG, GLS, ES y CIP, mientras que para la discretización de la variable temporal se hace uso del esquema Backward-Euler. En función del análisis *a posteriori* realizado, se implementa un algoritmo computacional espacio temporal adaptativo. Se presentan resultados numéricos que ilustran la teoría desarrollada y el funcionar de los estimadores de error.

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A linear Uzawa-type solver for nonlinear transmission problems

Thomas Führer *

Abstract

We propose an Uzawa-type iteration for the Johnson–Nédélec formulation of a Laplace-type transmission problem with possible (strongly monotone) nonlinearity in the interior domain. In each step, we sequentially solve one BEM for the weakly-singular integral equation associated with the Laplace-operator and one FEM for the linear Yukawa equation. In particular, the nonlinearity is only evaluated to build the right-hand side of the Yukawa equation. We prove that the proposed method leads to linear convergence with respect to the number of Uzawa iterations. Moreover, while the current analysis of a direct FEM-BEM discretization of the Johnson–Nédélec formulation requires some restrictions on the ellipticity (resp. strong monotonicity constant) in the interior domain, our Uzawa-type solver avoids such assumptions.

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Adaptive finite element methods for sparse PDE–constrained optimization

Alejandro Allendes *   Francisco Fuica *   Enrique Otárola *

Abstract

We propose and analyze reliable and efficient a posteriori error estimators for an optimal control problem that involves a nondifferentiable cost functional; control constraints are also considered. To approximate the solutions to the state and adjoint equations we consider piecewise linear discretizations whereas two different strategies are used to approximate the control variable: piecewise constant and piecewise linear discretizations. For both solution techniques we devise an error estimator that can be decomposed as the sum of four contributions: two contributions that account for the discretization of the control variable and the associated subgradient, and two contributions related to the discretization of the state and adjoint equations. On the basis of the devised a posteriori error estimators, we design simple adaptive strategies that yield optimal rates of convergence for the numerical examples that we perform.

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MIXED-PRIMAL FINITE ELEMENT METHODS FOR STRESS-ASSISTED DIFFUSION PROBLEMS

Gabriel N. Gatica* Bryan Gomez-Vargas† Ricardo Ruiz-Baier‡

Abstract

We analyse the solvability of a static coupled system of PDEs describing the diffusion of a solute into an elastic material, where the process is affected by the stresses generated by the solid motion. The problem is formulated in terms of solid stress, rotation tensor, solid displacement, and concentration of the solute. Existence and uniqueness of weak solutions follow from adapting a fixed-point strategy decoupling linear elasticity from a generalised Poisson equation. We then construct mixed-primal and augmented mixed-primal Galerkin discretisations based on adequate finite element spaces, for which we rigorously derive a priori error bounds. The convergence of these methods is confirmed through a set of computational tests in 2D and 3D.

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A DPG method for the Kirchhoff–Love plate bending model

Thomas Führer [*] Norbert Heuer [†] Antti H. Niemi [‡]

Abstract

We present an ultraweak variational formulation for a variant of the Kirchhoff–Love plate bending model. Based on this formulation, we introduce a discretization of the discontinuous Petrov–Galerkin type with optimal test functions (DPG). This scheme is well posed and converges quasi-optimally.

The variational formulation and its analysis require tools that control traces and jumps in H^2 (standard Sobolev space of scalar functions) and $H(\operatorname{div}\operatorname{Div})$ (symmetric tensor functions with L_2-components whose twice iterated divergence is in L_2), and their dualities. These tools are developed in two and three spatial dimensions.

Theoretical results are confirmed by numerical experiments.

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Variational formulation of time-fractional parabolic equations*

MICHAEL KARKULIK†

Abstract

We consider initial/boundary value problems for time-fractional parabolic PDE of order $1/2 < \alpha < 1$, that is, $\partial_t^\alpha u - \Delta u = f$ where ∂_t^α is a fractional time-derivative. Equations of this kind model diffusion phenomena where the mean-square displacement of a diffusing particle scales non-linear in time (as opposed to e.g., the well-known Brownian motion). Recently, researchers have started to analyze finite element methods with respect to their ability to approximate solutions of fractional PDE. In our talk, based on the work [1], we present a variational formulation of time-fractional parabolic equations which resembles classical results for parabolic PDE. This includes the extension of operators defined on real-valued Sobolev spaces to their Banach space-valued counterparts, the so-called *Sobolev-Bochner spaces*, as well as Sobolev Embedding results. This way, we provide a theoretical underpinning for the numerical analysis of such equations.

Key words: Fractional diffusion, Initial/boundary value problem, Well-posedness

Mathematics subject classifications (1991): 26A33, 35K15, 35R11

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UN MÉTODO DE ELEMENTOS FINITOS ESTABILIZADOS DE BAJO ORDEN A DIVERGENCIA NULA PARA EL PROBLEMA DE BOUSSINESQ ESTACIONARIO

Alejandro Allendes, * Gabriel R. Barrenechea, † César Naranjo ‡

Abstract

En este trabajo proponemos y analizamos un nuevo método de elementos finitos estabilizados para las ecuaciones de Navier-Stokes y temperatura acopladas (o ecuaciones de Boussinesq). El método es construido usando elementos conformes de bajo orden para la velocidad y temperatura, y elementos constantes a trozos para la presión. Con la ayuda del espacio de Raviart–Thomas de más bajo orden, se construye una extensión de los saltos de la presión discreta, de tal manera que cuando esta extensión es añadida al campo de velocidad conforme, la velocidad resultante es solenoidal (con el costo de ser no conforme). Este campo es entonces el que alimenta las ecuaciones de momento y temperatura, garantizando que los términos convectivos en estas ecuaciones son antisimétricos, sin la necesidad de ser alterados, simplificando así el análisis del método resultante. La existencia de soluciones, estabildiad discreta, y convergencia óptima es probada tanto para el campo de velocidad conforme, como para la correspondiente contraparte a divergencia nula no conforme. Resultados numéricos confirman los resultados teóricos, así también como la ganancia que entrega la velocidad solenoidal discreta por sobre la velocidad conforme.

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A stabilised finite element method for the convection–diffusion–reaction equation in mixed form

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Abstract

This work is devoted to the approximation of the convection–diffusion–reaction equation using a mixed, first order, formulation. We propose, and analyse, a stabilised finite element method that allows equal order interpolations for the primal and dual variables. This formulation, reminiscent of the Galerkin least-squares method, is proven stable and convergent. In addition, a numerical assessment of the numerical performance of different stabilised finite element methods for the mixed formulation is carried out, and the different methods are compared in terms of accuracy, stability, and sharpness of the layers for two different classical test problems.

Joint work with:
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An a posteriori error estimator for the MHM method applied to Stokes/Brinkman equations

Rodolfo Araya * Ramiro Rebolledo † Frédéric Valentin ‡

Abstract

In this work we introduce and analyze an a posteriori error estimator for the Multiscale Hybrid-Mixed (MHM) method, introduced in [1], applied to Stokes and Brinkman equations.

The error estimator is based on face-residual computations using the second level numerical solution obtained with the MHM method. We prove that this error estimator is locally efficient and reliable, up to a high order term, with respect to natural norms.

We also show that the h.o.t. appearing in the reliability analysis can be neglected in a general computation, if we use a local refined mesh for the second level computations.

We provide several numerical results illustrating the good performance of the estimator, and showing the behavior of the associated adaptive algorithm.

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On exponential stability for thermoelastic plates – a comparison of different models*

Mauricio Sepúlveda C. †

Joint work with
J.E. Muñoz Rivera (LNCC, Petrópolis, Brasil),
R. Racke, (Univesrität Konstanz) and
O. Vera Villagrán (Universidad del Bio-Bio, Chile)

Abstract

We consider different models of thermoelastic plates in a bounded reference configuration: with Fourier heat conduction or with the Cattaneo model, and with or without inertial term. Some models exhibit exponential stability, others are not exponential stable. In the cases of exponential stability, we give an explicit estimate for the rate of decay in terms of the essential parameters appearing (delay $\tau \geq 0$, inertial constant $\mu \geq 0$). This is first done using multiplier methods directly in L^2-spaces, then, second, with eigenfunction expansions imitating Fourier transform techniques used for related Cauchy problems. The explicit estimates allow for a comparison. The singular limits $\tau \to 0$, and $\mu \to 0$ are also investigated in order to understand the mutual relevance for the (non-) exponential stability of the models. Numerical simulations underline the results obtained analytically, and exhibit interesting coincidences of analytical and numerical estimates, respectively.

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