# *Dedicated to Professor Francisco J. Lisbona on the occasion of his 65th birthday*

## *Preface*

The construction, analysis and application of numerical methods to solve ordinary and partial differential equations are among the main research fields in today's scientific computing and they are of great interest in applied mathematics. This special issue is composed from research works on fundamental theoretical results as well as applications of advanced numerical techniques for Partial Differential Equations showing their efficiency, reliability and robustness. The selected papers included in this special issue were presented at the workshop "Numerical Methods for Ordinary and Partial Differential Equations and Applications" held from $3^{rd}$ to $5^{th}$ of September of 2012 at the University of Zaragoza (Spain) and dedicated to the $65^{th}$ birthday of Professor Francisco J. Lisbona. This workshop gathered close collaborators and friends of Professor Lisbona, junior researchers that he has mentored during his professional career and many of his students.

The scientific program included contributed talks by many invited speakers, who presented recent results in areas where Professor Lisbona has been among the main forces advancing the research. More than fifty participants from France, Russia, Ireland, the Netherlands, Germany, USA, Israel, and, of course, Spain contributed to the workshop success. The diversity of the presentations and the papers included in this special issue show the broad research interests of Professor Lisbona and provide an overview of many of the research topics in which he has had visible impact. We would like to thank everyone involved in the publication process of this IJNAM volume and especially to both the authors and the referees for their hard work, understanding, and cooperation. We also wish to thank the sponsors of the conference: the Spanish Government (via project MTM2011-15298-E), the University of Zaragoza and the Instituto Universitario de Matemáticas y Aplicaciones of University of Zaragoza. Thanks also go to the members of the Scientific Committee, to all the attendees for their participation in the conference, and to the research group Numerical Methods for Partial Differential and Integral Equations for providing excellent organization of the event.

On behalf of all the contributors, we dedicate this volume to our teacher, friend and colleague Francisco J. Lisbona.

We are greatly pleased to introduce this collection of papers in honor of Francisco Lisbona, Professor at the Department of Applied Mathematics of the University of Zaragoza. Francisco Lisbona is an applied mathematician who has extensively contributed to the field of numerical solution of ordinary and partial differential equations and scientific computing. He has authored or coauthored more than 90 scientific publications in renowned international journals in numerical analysis and its applications by bridging solid mathematical theory, scientific computing, and applications in sciences and engineering.

Francisco Lisbona was born in Zaragoza, on December $15^{\text{th}}$, 1947 He graduated as a top student in his class from Cardenal Xavierre High School in Zaragoza. He demonstrated his talent for mathematics and his dedication to study it, and in 1965 he was admitted in the University of Zaragoza to continue his studies. He graduated with degree in Mathematics in 1970 and during the first two years after graduation he combined teaching in high school with research in the Astronomy Department of the University of Zaragoza. After that, in 1972, Francisco moved to the University of Bilbao where studied and worked towards obtaining his PhD degree under the supervision of Professor Mariano Gasca. His PhD thesis work was in approximation theory, and during this time Francisco was also teaching at the University of Bilbao.

After receiving his PhD degree in 1976, which was awarded with *Distinction*, Francisco Lisbona worked at the University of Bilbao for a year and during this time he received one of the first national faculty positions in numerical analysis in Spain. This position allowed him to move back University of Zaragoza, Department of Differential Equations, which was led by Professor Rodriguez Vidal. Upon his arrival, he was put in charge of developing the numerical analysis program at this department, a discipline which was then making its first steps in Spain.

At this time, in collaboration with Manuel Calvo, Lisbona started his work on the numerical integration of initial value problems (IVP) for ordinary differential equations (ODEs). In the late seventies, he visited during the Department of Applied Mathematics of the Université de Rennes (France) for one year. This visit had notable impact on his future as scientist, since the focus of his research shifted to numerical methods for partial differential equations, and it remains his primary field of research to this day. In Rennes he met Professor Michel Crouzeix and at the beginning they started working on numerical methods for IVP, in particular in the analysis of the stability of multistep methods with variable step and order. During this visit, driven by his scientific curiosity, Professor Lisbona also invested time in studying the analytical aspects of numerical methods for partial differential equations and more specifically, the finite element methods. He became well versed in these modern numerical techniques and upon returning to University of Zaragoza he was put in charge of the group in numerical analysis for partial differential equations. In the mean time, Professor Rodriguez Vidal retired and Professor Lisbona was promoted to full professor, a position which he holds now.

One specific topic which caught Lisbona's interest was the numerical approximation of singularly perturbed problems and this became one of the main research lines that he and his group have followed since then. During the following years his professional career was also connected with the Université de Pau et des Pays de L'Adour (France). He had the fortune to spend some months there, and he met a number of scientists working in finite element methods for partial differential equations. One of them was Professor Jean-Marie Thomas, with whom Lisbona established a good research and personal relationship. Also there, he started to work

with Jean Genet and Monique Madaune-Tort in singularly perturbed problems, a collaboration which continues to be productive to this day.

Approximately at the same time Lisbona advised Carmelo Clavero, one of his first students. The thesis of Clavero was on the analysis of difference methods for singularly perturbed boundary value problems. In this line of research Lisbona began collaborations with world-known experts in this area such as Professors John Miller and Grigorii Shishkin and he continues to have close professional and personal relationships with them.

One thing that is characteristic of Professor Lisbona is that he has the ability to direct, advise and support junior researchers, at the same time providing them with opportunities to start independent research and promoting their ideas. His scientific versatility and pedagogical talent allowed him to attract PhD students and junior researchers to the "Numerical Methods for Partial Differential and Integral Equations" research group which is currently very active and of which Lisbona is the proven leader.

In the late eighties Lisbona advised Gloria Aguilar and Juan Carlos Jorge whose theses were also in the area of singularly perturbed problems. The PhD work of Gloria was more theoretical and focused on the coupling between elliptic and hyperbolic equations, while the thesis of Juan Carlos was on fractional step methods for the numerical solution of parabolic problems involving singularly perturbed operators. Another member of the research group, Francisco Javier Sayas, influenced and advised by Lisbona went to Rennes to pursue PhD degree with Professor Crouzeix. During the eighties and early nineties, in collaboration with Carmelo and Juan Carlos, Professor Lisbona published a large number of papers on numerical solution of singularly perturbed problems. Also, as a result of the PhD thesis of Gloria, he started research on capillary barriers, in which Carmelo, Juan Carlos, Gloria, Javier and another young student, José Luis Gracia, participated. Following this line, together with Javier Sayas, he advised another PhD student Ricardo Celorrio whose thesis was on boundary element methods for a stationary flux problem around a tunnel. Another work on singularly perturbed problems is contained in the thesis of another of Lisbona's students, José Luis Gracia. The thesis is on the analysis of high-order schemes on Shishkin meshes for singular perturbation problems and was defended in the late nineteens. Without a doubt, Professor Lisbona's research on singular perturbation problems had a significant impact in this area.

In the late nineties Lisbona met the Russian Professor Petr Vabishchevich, and this friendship and collaboration initiated another change in his career. They started research on numerical models in poroelasticity involving finite difference discretizations on collocated and staggered grids. Professor Vabishchevich and Lisbona jointly participated in an INTAS collaborative project between Russian, Belorussian, Lithuanian and German Institutions. This gave Lisbona the opportunity to interact and work with other colleagues like Professors Oleg Iliev and Piotr Matus. One of the major results was reported in a collaborative work with Petr Vabishchevich and Academician Alexandr Samarskii (in Russian). In pursuing the research on numerical modeling of poroelastic materials, he attracted to the group Francisco Gaspar. Gaspar defended his PhD in Oviedo University, and, at the time, was working at the University of Zaragoza. Lisbona and Gaspar focussed on exploring finite difference discretizations for the poroelasticity and they stumbled upon the pressing need of using fast solvers for the resulting large sparse systems of algebraic equations. Lisbona's great intuition led to shifting the research towards applying multilevel (multigrid) methods. The multigrid methods were not

something new for the group. Francisco Gaspar had spent some time before in the Sankt Augustin research center working with several top multigrid experts in Europe. Their idea, which proved to lead to very successful algorithms was to apply distributive smoothers for the multigrid algorithms for poroelastic systems. This, in turn, opened another avenue for successful collaboration with Professor Cornelis W. Oosterlee, whose expertise was on such this type of methods. In the coming years, the multigrid research gained strength in professor Lisbona's group, and is currently one of the main topics of research.

One prominent contribution of Professor Lisbona and his group is the extension of the multigrid techniques, and especially of the local Fourier analysis to general semi-structured triangular grids. That allowed them to design algorithms which are easy to parallelize and perform with the same efficiency as the multigrid methods on simple square grids. This work was carried out first in Carmen Rodrigo's thesis, defended in 2010, under the supervision of Professors Lisbona and Gaspar. Recently, the techniques were also extended to discretizations on Voronoi meshes, by another of the PhD students in the group, Pablo Salinas, also advised by Professors Lisbona and Gaspar. One of the applications in Pablo's thesis focusses on the application of multigrid techniques to the Darcy–Oberbeck–Boussinesq model, which is closely related to Lisbona's emerging research interests in the numerical modeling of $CO_2$ storage.

It is difficult in such a short summary to comment on the all the research lines carried out by Professor Lisbona. We hope that the articles included in this special issue will give a glimpse of the broad and diversified research interests of Professor Lisbona. He is an outstanding scholar and his work has made and continues to make significant impact on many aspects of numerical analysis. His high requirements in regard to the research done by him and by his students and collaborators are complemented by a great care about everyone and everything in his group. Lisbona has influenced the professional and personal development of all who have had a chance to work with him. The group which he has created over the years is an example of how research interests, philosophy and personal friendship can be combined to bring success.

We would like to congratulate Professor Lisbona on the occasion of his 65th birthday and sincerely wish him all the best in personal and professional life.

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