Full Membership Application to the International Mathematical Union

Ecuadorian Mathematical Society

History: the beginnings

The beginning of the academic mathematics history in Ecuador goes back to the year 1869, when the first technical university ("Escuela Politécnica Nacional", EPN) was founded as a part of the former Central University "Santo Tomás" in Quito. The first Ecuadorian Faculty of Mathematics was a constitutive part of this new higher education institution. Its initial academic activities were coordinated by the German and Italian scholars Revd. Johannes Baptist Menten, Revd. Teodor Wolf, and Revd. Luis Sodiro.

For more than a century, courses on mathematics were offered at universities only as support for engineering and similar careers. This changed in 1975 when the Department of Mathematics was created at the -- meanwhile independent -- National Technical University ("Escuela Politécnica Nacional", EPN) in Quito, with the enthusiastic help of Prof. Bernard Chevreau (France) and Prof. William Voxman (USA), who spent three and one years in Ecuador, respectively. A first generation of Ecuadorian mathematicians were educated there and were afterwards supported for graduate studies abroad.

After obtaining their Ph.D. degrees at universities in Europe and the United States, some of these mathematicians returned to Ecuador during the 80's. Most of them joined the Department of Mathematics at EPN as professors, while others supported the creation of new careers in mathematics at other ecuadorian universities. At present, programs of study in mathematics are offered at three other higher education institutions: the "Escuela Politécnica del Litoral (ESPOL)" in Guayaquil, the "Universidad San Francisco de Quito (USFQ)" and the "Universidad Central (UCE)" in Quito.

The Ecuadorian Mathematical Society ("Sociedad Ecuatoriana de Matemática" SEdeM) was formed in 1967 at the initiative of some enthusiastic professors interested in the fostering of mathematics in Ecuador. Originally, its main goal was the improvement of the quality of education in mathematics at all levels countrywide. Later on, this goal was extended and since then the SEdeM is expected to provide an environment where Ecuadorian mathematicians can exchange ideas and devise concrete actions aiming at the enhancement of the general background conditions for both research and education in mathematics in Ecuador. From 41 members in 2006, the Ecuadorian Mathematical Society increased that number to a total of 135 up to date.

One example of such concrete actions have been the Ecuadorian Conferences on Mathematics, organized since 1986 by the Department of Mathematics at EPN on a biennial basis. These conferences follow three main objectives. First, they intend to support the improvement of the mathematics education standards through specialized

courses addressed to school teachers. Second, the meetings constitute a forum where Ecuadorian professors and researchers have the opportunity to exchange ideas and propose possible new research directions, in most cases with the presence of prominent foreign invited speakers. Finally, mathematicians working outside academia (a fast growing group in Ecuador in recent years) expose their experiences in the form of talks directed to a broader audience of professionals.

History: recent years

Adverse economic conditions and wrong government policies lead to a general crisis and massive emigration in Ecuador during the nineties. As a consequence, public education suffered from a sustained drop in quality, and mathematics was not the exception. To take a single representative example, no tenured position could be filled for more than 10 years at the Department of Mathematics of the EPN, due to the lack of properly qualified candidates. Similar figures were registered at the other universities. Professors were overloaded with teaching duties and research almost stagnated.

This situation has started to revert in the new century. A young generation of mathematicians that had obtained their doctoral degrees in Europe and the Americas decided to return to Ecuador and were offered positions at some universities. At the same time, the German Academic Exchange Service agreed to finance a cooperation project between the mathematics departments at EPN and at the Technical University of Berlin (TU Berlin) aiming at the education of the first PhD students in Ecuador.

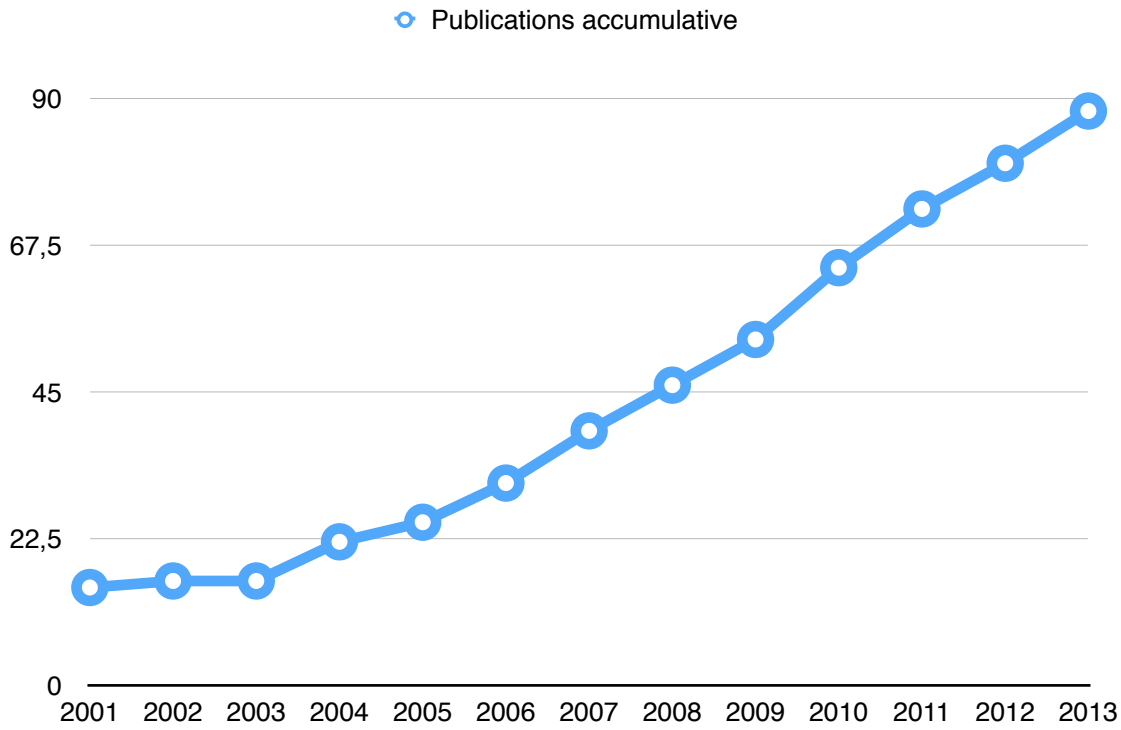
Accordingly, there has been a boost in research activities during the last 10 years, which ended up in the creation of the *Research Center on Mathematical Modelling (ModeMat)* in the year 2013. The center was created with the important support of the Ecuadorian government and the EPN, where the center is located. It aims at carrying out high quality research in applied mathematics and to support the development of mathematical models for several sectors of the society (for more details see the special section below).

The SEdeM highly profited from this revitalization of the last years. Since 2006, both experienced professors and young researchers are active part of the society.[1] Moreover, the efforts to integrate Ecuador into the international community yielded important results. Ecuador is an associate member of the *International Mathematical Union* since 2007 and a full member of the *Unión Matemática de América Latina y el Caribe (UMALCA)* since 2012. Within this context, and being convinced that a full membership into the International Mathematical Union will further enhance the mathematical development of the country, we apply for a full membership of the SEdeM into the IMU.

Research

Research in pure and applied mathematics in Ecuador has increased significantly during the recent years. From 15 international refereed articles written by Ecuadorian mathematicians up to the year 2000, the number has increased to 88 up to the present. The publications appeared in leading journals like *SIAM Journal on Control and Optimization*, *Journal of Algebra* or the *Proceedings of the American Math. Society*.

[1] More details can be found at the Society's webpage: http://www.sedem.org.ec



Nowadays, the different mathematics departments have active researchers in areas like discrete mathematics, numerical analysis, optimization, among others.

In December 2002 the first Ph.D. program on mathematics in Ecuador started. The program was a joint project between the Escuela Politécnica Nacional (EPN Quito), the Technical University of Berlin, and the German Academic Exchange Service (DAAD). Seven Ph.D students were formed as highly qualified researchers capable of formulating mathematical models for practical problems arising from industry and engineering, and designing efficient algorithms for their solution. After finishing their Ph.D. theses, these researchers were offered permanent positions at EPN, where they have since then been working as full time professors, with an active research profile.

The Ph.D. program also marked the beginning of more intense research activities in the Department of Mathematics at EPN Quito. For instance, two research groups have been constituted, working in the fields of continuous and discrete optimization, respectively. The groups involve around 10 professors and several advanced undergraduate students. They hold regular research seminars at EPN and actively participate in national and international meetings. There are several research projects and international cooperations currently going on. As an indicator of their visibility, the groups have received in the last years the visit of many mathematicians from different countries (Argentina, Austria, Canada, Chile, Colombia, Germany, Hungary, Mexico, Netherlands, Switzerland, USA).

Research Center on Mathematical Modeling

As a consequence of the intense positioning strategy of mathematics within Ecuador, the *Research Center on Mathematical Modelling (ModeMat)* was created at the beginning of 2013. The center is a result of the awareness, by the authorities of the EPN and the Ecuadorian Government, of the importance of research in applied mathematics as a cornerstone for the development of other scientific and technological areas.

The *Research Center on Mathematical Modelling* aims to develop new mathematical and computational techniques, and build innovative mathematical models to solve problems arising from different application areas. Initially, the center will conduct research projects in three areas:

1. Logistics and Transportation,
2. Optimization and Control,
3. Modelling and Simulation in Biosciences.

The board of the center is shared by the EPN and the Ecuadorian government. The center is affiliated to the EPN but has a countrywide status, which means that researchers from other higher education institutions and public research institutes can get support for project proposals within the research areas identified above. The financial support of the projects may come from different sources.

To ensure that the quality of the research developed at the Center meets international standards, the Center has a *Scientific Committee*, composed by international prestigious scientists with expertise in the management of similar research centers in other countries. The primary function of the Scientific Committee is to monitor the Center's scientific productivity . The members of the Scientific Committee shall conduct periodic evaluations of the research taking place at the Center, and propose strategic decisions to the board, which may include opening or closing research areas.

One of the main expected impacts of the center is the foster of graduate programs in Applied Mathematics. The research projects will be formulated in such a way that they constitute a framework for the development of master and doctoral theses. Additionally, through international networking, the center aims to increase the academic mobility, in particular the exchange of researchers and graduate students.

Universities and Education

Although there are 62 universities in Ecuador at the present day, only 10 offer careers related to mathematics. Six of them educate high school mathematics teachers, while the remaining 4 (EPN, ESPOL, UC and USFQ) train future mathematicians for working both in academia and industry.

In recent years, these universities have started several postgraduate programs in areas of applied mathematics. Currently, there are 6 master programs: three in applied statistics, one in operations research and two in mathematical education. The education is highly applied and has an important impact on many sectors of the society: financial institutions, oil industry, education, etc.

The Ecuadorian Mathematical Society and the universities in the country are also deeply involved in the improvement of mathematical education at all levels. Additionally to the master program on mathematical education directed to school teachers and organized by the Universidad Central del Ecuador, mathematicians from different universities are involved in studies about the didactics of mathematics in Ecuadorian schools.

In that spirit, workshops across the country are periodically organized in order to provide up to date trainings on the teaching of mathematics. The work is in many cases coordinated with the Ministry of Education of Ecuador.

A milestone in this context is the execution of the CLAVEMAT project, financed within the European Union's ALFA-III program since 2012 for a period of three years. The project involves four Latin American and two European countries, in a cooperative network of higher education institutions, with the objective of investigating the use of several virtual tools for improving the teaching of mathematics in the last years of high school and the first years of university. Special attention is paid to mechanisms that have the potential to enhance the chances of students coming from economic disadvantaged regions to successfully pursuing a university degree in STEM fields.

The support to the organization of mathematical contests has also been an important activity of the Society. Currently, the SEdeM sponsors the organization of local contests all over the country, and yearly organizes the nationwide *Olimpiada de Matemática*, which will reach its 11th edition in 2014. In the last two years, the Ecuadorian government has supported the organization of the Olympiad through the Secretary for Higher Education and Research (SENESCYT), recognizing the importance of this competition as a mean for fostering the interest in mathematics in schools and high schools.

Regional impact and international visibility

An important goal of the Society in the last years has been the impulse of mathematics in the region and the increase in visibility of Ecuadorian mathematics worldwide. With that in mind, the Society organized in 2008 the first *Latin American Workshop on Optimization and Control (LAWOC)*, with the aim of gathering Latin American researchers working in these areas and enhance their future scientific collaboration. The meeting had an important impact and subsequent versions have been organized in Rosario-Argentina (2010) and Valparaíso-Chile (2012). The next LAWOC will take place this year in Lima-Perú.

To contribute to the mathematical training of undergraduate and graduate students from the Andean region, two mathematical schools took place in Quito recently. The first *EMALCA Ecuador* was co-organized with the UMALCA in 2010, with block courses on varied mathematical topics taught by Latin-American Professors. In 2013 the first *Escuela de Control y Optimización (ECOPT)* was organized in Quito jointly with faculty of the Universidad Técnica Federico Santa María from Chile. The school hosted students from Colombia, Ecuador, Perú and Chile, who attended block courses on optimization and control topics for two weeks. The second ECOPT will take place in Santiago-Chile in 2016.

This year in june the first *Congress on Biomedical Engineering and Mathematical Modelling in Bioscience* will take place in Quito. The event is a joint effort of the

mathematical and the bioengineering communities to foster this area of knowledge in the region and to position the country as a research spot on these fields. Among the invited speakers are worldwide prestigious mathematicians like Prof. Carlos Castillo-Chávez from Arizona State University.

On february 2014 the Ecuadorian proposal for organizing the *XIV Escuela Latinoamericana de Verano de Investigación Operativa (ELAVIO 2015)* was considered and approved by the Executive Committee of the *Association of Latin-Iberoamerican Operational Research Societies (ALIO)*. The ELAVIO has a long tradition in the region as an important meeting for getting up to date with different topics of operations research developed in the region. The organization of the 2015 version will not only position the Ecuadorian mathematical community, but also will make it possible for students from neighboring countries to attend such a prestigious school.

Committee for Mathematics

The following ecuadorian mathematicians constitute the Committee for Mathematics:

- Dr. Luis Horna
- Dr. Germán Rojas
- Dr. Luis M. Torres
- Dr. Polo Vaca

Refereed Publications (2004-2013)

The following list consists of refereed publications produced by researchers working at Ecuadorian institutions at the time of publication.

1. Bustamante J. C. (2004). The classifying space of a bound quiver. *Journal of Algebra*. Vol. 277, pp. 431-455.
2. De Los Reyes J. C. & Kunisch K. (2004). A comparison of algorithms for control constrained optimal control of the Burgers equation. *Calcolo*. Vol. 41, pp. 203–225.

3. De Los Reyes J. C. (2004). A primal-dual active set method for bi- laterally control constrained optimal control of the Navier-Stokes equations. *Numerical Functional Analysis and Optimization*. Vol. 25, pp. 657–683.

4. Torres L. M. (2004). On cliques in κ-set packing. Cologne-Trieste Workshop 2004 Proceedings. *Electronic Notes in Discrete Mathematics*. Vol. 17, pp. 263–267.

5. Calahorrano M. & Mena H. (2004). Multiple solutions for inhomogeneous nonlinear elliptic problems arising in astrophyiscs. *EJDE*. Vol. 49, pp. 1–10.

6. Mena H. & Benner P. (2004). BDF Methods for Large-Scale Differentiall Riccati Equations. In Proceedings Sixteenth International Symposium on: Mathematical Theory of Network and Systems, MTNS 2004, Leuven, Belgium.

7. De Los Reyes J. C. & Kunisch K. (2005). A semi-smooth Newton method for control constrained boundary optimal control of the Navier-Stokes equations. *Nonlinear Analysis: Theory, Methods and Applications*. Vol. 62, pp. 1289–1316.

8. Calahorrano M. & Mena H. (2005). Remarks on inhomogeneous elliptic problems arising in astrophysics. *E. J. Qualitative Theory of Diff. Equ.*. Vol. 19, pp. 1–12.

9. Assem I., Bustamante J. C., Castonguay D. & Novoa C. (2005). A note on the fundamental group of a one-point extension. *Proyecciones*. Vol. 24, pp. 79-87.

10. De Los Reyes J. C. (2006). Primal-dual active set method for control constrained optimal control of the Stokes equations. *Optimization Methods and Software*. Vol. 21, pp. 267–293.

11. Gutiérrez S., Krumke S., Megow N., Vredeveld T. (2006). How to Whack Moles. *Theoretical Computer Science*. Vol. 361, No. 2, pp. 329–341.

12. De Los Reyes J. C. & Kunisch K. (2006). A semi-smooth Newton method for regularized state-constrained optimal control of the Navier-Stokes equations. *Computing*. Vol. 78, pp. 287–309.

13. Bustamante J. C. & Castonguay D. (2006). Fundamental groups and presentations of algebras. *Journal of Algebra and its Applications*. Vol. 5, pp. 549-562.

14. Bustamante J. C. (2006). The cohomology structure of string algebras. *Journal of Pure and Applied Algebra*. Vol. 204, pp. 616- 626.

15. Bustamante J. C. (2006). Homotopy and bound quivers. *Ann. Sci. Math. Québec*. Vol. 30, pp. 175-203.

16. De Los Reyes J. C. & Tröltzsch F. (2007). Optimal control of the stationary Navier-Stokes equations with mixed control-state constraints. *SIAM Journal on Control and Optimization*. Vol. 46, pp. 604–629.

17. Calahorrano M. (2007). Existencia de soluciones positivas para problemas no lineales con discontinuidades indefinidas. *Boletín de la Sociedad Matemática Mexicana*. Vol. 13, pp. 95-102.

18. Martens M., Salazar F. & Skutella M. (2007). Convex combinations of single source unsplittable flows. *Lectures Notes in Computer Science*, Proceedings of the 15th Annual European Symposium on Algorithms (ESA'07). Vol. 1, pp. 395-406.

19. De Los Reyes J. C. & Tröltzsch F. (2007). Flow control with regularized state constraints, *Notes on Numerical Fluid Mechanics and Multidisciplinary Design (NNFM)*, Vol. 95, 353-366, Springer-Verlag.

20. De Los Reyes J. C. & Yousept I. (2007). Boundary optimal flow control with state constraints. *Proceedings in Applied Mathematics and Mechanics*. Vol. 1, pp. 2060029-2060030.

21. Mena H. & Benner P. (2007). Numerical Solution of Differential Riccati Equations Arising in Optimal Control for Parabolic PDEs. *Proceedings in Applied Mathematics and Mechanics*. Vol. 1, pp. 2060063-2060064.

22. Carnarius A., De Los Reyes J. C., Günther B., Thiele F., Tröltzsch F. & Wachsmuth D. (2007). Numerical study of the optimization of separation control. AIAA 2007-0058, 45th AIAA Aerospace Sciences Meeting and Exhibit.

23. Calahorrano M. (2007). Existence and multiplicity of solutions for elliptic problems with indefinite discontinuous nonlinearities. Proceedings in Applied Mathematics and Mechanics. Vol. 1, pp. 1040303-1040304.

24. Casas E., De Los Reyes J. C. & Tröltzsch F. (2008). Sufficient second-order optimality conditions for semilinear control problems with pointwise state constraints. *SIAM Journal on Optimization*. Vol. 19, pp. 616-643.

25. De Los Reyes J. C. & Griesse R. (2008). State constrained optimal control of the stationary Navier-Stokes equations. *Journal of Mathematical Analysis and Applications*. Vol. 343, pp. 257-272.

26. De Los Reyes J. C., Merino P., Rehberg J. & Tröltzsch F. (2008). Optimality conditions for state-constrained PDE control problems with finite-dimensional control space. *Control and Cybernetics*. Vol. 37, pp. 5-38.

27. Benner P., Mena H. & Saak J. (2008). On the Parameter Selection Problem in the Newton-ADI Iteration for Large Scale Riccati Equations. *Electronic Transactions in Numerical Analysis*. Vol. 29, pp. 136-149.

28. De Los Reyes J. C., Meyer C. & Vexler B. (2008). Finite element error analysis for state-constrained optimal control of the Stokes equations. *Control and Cybernetics*. Vol. 37, pp. 251-284.

29. De los Reyes J. C. & González S.(2008). Flow of Bingham fluids in a bounded channel. Memorias EXPRIME.

30. Torres L. M., Torres R., Borndörfer R., Pfetsch M. (2008). Line Planning on Paths and Tree Networks with Applications to the Quito Trolebús System. ATMOS 2008 - 8th Workshop on Algorithmic Approaches for Transportation Modeling, Optimization, and Systems.

31. Lóczi, L. & Páez Chávez, J. (2009). Preservation of bifurcations under Runge-Kutta methods. *International Journal of Qualitative Theory of Differential Equations and Applications*. Vol. 3(1-2), pp. 81–98.

32. De Los Reyes J. C. & González S. (2009). Path following met- hods for stationary laminar Bingham fluids. *ESAIM: Mathematical Modelling and Numerical Analysis*. Vol. 43, pp. 81-117.

33. De Los Reyes J. C & Yousept I. (2009). Regularized state-constrained boundary optimal control of the Navier-Stokes equations. *Journal of Mathematical Analysis and Applications*. Vol. 356, pp. 257-279.

34. Bustamante J. C., Dionne J. & Smith D. (2009). (co)Homology Theories for oriented algebras. *Communications in Algebra*. Vol. 37, pp. 1516-1534.

35. Salazar F. & Skutella M. (2009). Single-source k-splittable min- cost flows. *Operations Research Letters*. Vol. 37(2), pp. 71-74.

36. De Los Reyes J. C. & Kunisch K. (2009). Optimal control of partial differential equations with affine control constraints. *Control and Cybernetics*. Vol. 38, pp. 1217-1250.

37. De Los Reyes J. C. & Kunisch K. (2009). On some nonlinear optimal control problems with vector-valued affine control constraints. In Optimal Control of Coupled Systems of PDE, K. Kunisch, G. Leugering, J. Sprekels and F. Tröltzsch (Eds.), 105-122, Birkhäuser Verlag.

38. De Los Reyes J. C. & González S. (2010). Numerical simulation of two-dimensional Bingham fluid flow by semismooth Newton methods. *Journal of Computational and Applied Mathematics*. Vol. 235, pp. 11-32.

39. Merino P. & Tröltzsch F. & Vexler B. (2010). Error estimates for the finite element approximation of a semilinear elliptic control problem with state constraints and finite dimensional control space. *ESAIM-M2AN*. Vol. 44(1), pp. 167–188.

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41. Páez Chávez, J.(2010). Discretizing Bifurcation Diagrams near Codimension two Singularities. *International Journal of Bifurcation and Chaos in Applied Sciences and Engineering*. Vol. 20(5), pp. 1391–1403.

42. Holm E., Torres L. M. & Wagler A. (2010). On the Chvátal-rank of linear relaxations of the stable set polytope. *International Transactions in Operational Research*. Vol. 17(6), pp. 827–829.

43. Holm E., Torres L. M. & Wagler A. (2010). On the Chvátal-rank of Antiwebs. *Electronic Notes in Discrete Mathematics*. Vol. 36, pp. 183–190.

44. De Los Reyes J. C. (2010). On the optimization of steady Bingham flow in pipes. In Recent Advances in Optimization and its Applications in Engineering, M. Diehl, F. Glineur, E. Jarlebring and W. Michiels (Eds.), 379-388, Springer Verlag.

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46. Mena H. & Benner P. & Ezzatti P. & Quintana-Ortí E. & Remón A. (2010). Numerical Solution of Differential Riccati Equations on Hybrid CPU-GPU Platforms. Proceedings of ALAMA2010 - 2nd Meeting on Linear Algebra, Matrix Analysis, and Applications, p.p. 1-7.

47. Recalde D., Rutten C., Schuurman P. & Vredeveld T. (2010). Local Search Performance Guarantees for Restricted Related Parallel Machine Scheduling. Proceedings of LATIN 2010. *Lectures Notes in Computer Science*. Vol. 6034, pp. 108–119.

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52. Páez Chávez, J. (2011). Discretizing Dynamical Systems with Generalized Hopf Bifurcations. *Numerische Mathematik*. Vol. 118, pp. 229–246.

53. Merino P. & Neitzel I. & Tröltzsch F. (2011). On linear-quadratic elliptic control problems of semi-infinite type. *Applicable Analysis*. Vol. 90(6), pp. 1047-1074.

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57. Mena H. & Benner P. & Ezzatti P. & Quintana-Ortí E. & Remón A. (2011). Solving Differential Riccati Equations on Multi-GPU Platform. In J. Vigo-Aguilar (Ed.), Proceedings of the 11th International Conference on Computational and Mathematical Met- hods in Science and Engineering, CMMSE 2011, Vol. 1, pp. 178- 188.

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59. González S. & Borzi A. (2012). Multigrid solution of a linear Lavrentiev-regularized state-constrained parabolic control problem. *Numerical Mathematics: Theory, Methods and Applications*. Vol. 5, pp. 1-18.

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66. De Los Reyes J. C. & Schönlieb C.-B.(2013). Image denoising: Learning the noise model via nonsmooth PDE-constrained optimization. *Inverse Problems and Imaging*. Vol. 7(4), pp. 1183- 1214.

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