LAUDATIO

On the occasion of the Laurea Honoris Causa in Matematica to Jorge J. Moré

Università degli Studi di Napoli Federico II

Aula Magna Storica, 15 ottobre 2021

From Feodor Dostoevskij to his future wife: "I know that two and two make four - and should be glad to prove it too if I could - though I must say if by any sort of process I could convert 2 and 2 into five it would give me much greater pleasure".

Magnifico Rettore, dear colleagues,
It is a great honor and pleasure for me to deliver the Laudatio for Jorge J. Moré on the occasion of his Laurea Honoris Causa in Mathematics awarded by the University of Naples Federico II. I'm pleased not just because of the prestige and authoritativeness of Jorge Moré, but also because of my scientific and personal relationship with him, and my emotional connection with the University of Naples Federico II where I spent 30 years of my life.

The task of describing the merits of such a researcher as JM is undoubtedly very hard, although I am extremely grateful. His scientific achievements are so many, and they have had such a tremendous impact on the field of numerical optimization that my presentation clearly cannot be exhaustive.

JM was born in Havana, Cuba, on May 16, 1944 and emigrated to the United States in 1960. He completed his postgraduate studies at the Georgia Institute of Technology where he obtained a Master's degree in applied Mathematics in 1968. At the University of Maryland he received his PhD in Applied Mathematics with James Ortega and Werner Rheinboldt as advisors with a thesis on *A Class of Nonlinear Functions and the Convergence of Gauss-Seidel and Newton-Gauss-Seidel Iterations*. He started his career as assistant professor at Cornell University in 1970, then became a Senior Research Fellow at University of Cambridge, and after that, he became a Computer Scientist at the Mathematics and Computer Science Division at Argonne National Laboratory, where he has spent most of his career. His extraordinary work has earned him, among other honors, his nomination as Fellow of the Society for Industrial and Applied Mathematics and the Beale-Orchard-Hays Prize for Excellence in Computational Optimization.
He is also an Argonne Distinguished Fellow, the highest scientific ranking offered at the laboratory as recognition of exceptional scientific contributions.

The outstanding scientific curriculum of JM includes more than 100 papers with more than 30000 citations, with an h-index of 58, and 28 papers with more than 200 citations. However, all of these things are just a part of his many scientific merits. His research activity can be seen within the framework of the modern numerical optimization, and more generally of numerical analysis. Neverthless, it would be an understatement just to say that Jorge worked in the development of algorithms and software for large-scale optimization.

Rather than trying to give a summary of JM results which would go beyond our time limits, I will concentrate on just few of them, in order to highlight his attitude towards research, which has kept him interested in exploring new ways of tackling problems with a sharp focus on the applicability of the scientific results.

JM had an important role in the numerical analysis evolution and revolution, started in the 20th century, in which *the growth in power and availability of digital computers has led to an increasing use of realistic mathematical models in science and engineering, and numerical analysis of increasing sophistication is needed to solve these more detailed models of the world* (from the Britannica encyclopedia).

I will start with the seminal work of JM, with John Dennis and Charles Broyden on Quasi-Newton (QN) Methods. Just a few words to outline the problem.
Newton-Raphson's Method (NRM), the most famous method for solving algebraic equations, dates back to the second half of the 17th century in its very primitive version, and was initially derived as pure algebraic method. Very soon the connection with the nascent calculus, namely computing the tangent line approximation to a curve, was clear, and made it possible to naturally extend the method to the solution of systems of algebraic equations and minimization of n-variables functions. Indeed, the concept of derivative plays a key role in the NR method. Roots finding approaches (which date back the ancient Egypt) before calculus can just be seen as naif approximate versions of NRM.
It may appear strange or contradictory at first, the many efforts in the nineteen-sixties devoted to designing a version of the NRM without derivatives. The reason was that in many applications leading to the solution of systems of algebraic equations, the number of variables was very large and the computation of the Jacobian matrix (i.e. the matrix of the derivatives) was very costly or even impossible. And this was a key issue in the effective implementation of Newton type methods in order to fully exploit the potential of the up and coming computational infrastructures.
The goal was to mimic Newton's method without derivatives. The first quasi-Newton algorithm was proposed by William C. Davidon, a physicist working at Argonne National Laboratory in 1959. Charles Broyden, working on a nonlinear model of nuclear power unit, came up with two approximate formulas for the Jacobian matrix (the famous Broyden's rules), and more or less at the same time Roger Fletcher, Mike Powell, Donald Goldfarb, and David Shanno made similar discoveries.
Quoting Andreas Griewank in his very nice paper on the historical developments of QN methods: *reducing the linear algebra effort in the process looks more like an engineering trick than an algorithmic device of mathematical interest*. However, a rigorous analysis of QN methods has seen tremendous advances in the early seventies, showing that a beautiful mathemathics underlies the apparently surprising behavior of the QN methods. In this process, some papers by JM with Charles Broyden and John Dennis are milestones in the numerical optimization literature. Quoting again A.Griewank: (talking about *Charles Broyden and his fellow quasi-Newton musketeers*): *after a few years and in close collaboration with his coauthors John Dennis and Jorge Moré, a beautiful theory of superlinear convergence theory emerged, which was later built upon by other researchers and extended to many update formulas…..*
In particular, Jorge Moré least change characterization of the Broyden matrix with respect to the Frobenius norm leading to the proof of superlinear convergence is considered a key result in the QN methods theory.

Although it may seem strange and singular, rather than iterate on working on QN methods, JM decided to move to an (apparently) different topic: the trust region methods. Once again the decision was motivated by the desire to work on a key issue of numerical optimization, with a strong impact on the practical applicability of methods. The issue was the design of general strategies to get algorithms globally convergent, i.e. in which the convergence is guaranteed with an arbitrary initial point. Once again, a beautiful theory was stated, and in particular the papers *The Levenberg-Marquardt algorithm: implementation and theory J.J. Moré - Numerical analysis, 1978 – Springer* and *Computing a Trust Region Step. J. J. Moré and D. C. Sorensen – SISC 1983* are cornerstones for the topic. Once again, effective implementation solutions were strongly related to a deep theoretical analysis.

I will now move on to what JM indicates as "Synergistic Activities". According to the Oxford dictionary, *the adjective 'synergistic' relates to the interaction or cooperation of two or more agents to produce a combined effect greater than the sum of their separate effects*. In this case, the agents are the mathematicians, the computer scientists, the end users, that is scientists and not only scientists in a wide variety of areas. The applicability of the mathematical results is the main focus of these activities. The Applied Mathematics division at the Argonne National Laboratory, starting in the late seventies of last century was strongly involved in the design of numerical libraries, namely the Linpack and the Minpack libraries, which were not just a collection of numerical codes. In this process, JM has been a pioneer as leader of the Minpack project.

MINPACK-1 (M1) is a package for the numerical solution of systems of nonlinear equations and noninear least squares problems…is a research effort whose goal is the development of a systemized collection of quality optimization software…The goals of M1 are reliability, ease of use, and transportability…..reliability derives from the underlying algorithms having a sound theoretical basis which, for instance, guarantee global convergence and scale invariance. This is what reliability means at the algorithmic level. But there is also a software level: JM has pioneered new ways of thinking about extensive and numerical testing of a software through rigorous standard procedure: Minpack comes with a large collection of test problems on which the performance of the software have been measured on a huge number of computing systems available at that time.
About 20 years later, somewhat along the same lines, in the name of methodological rigor in providing objective information when benchmarking algorithms, Elizabeth Dolan and JM came up with the design of the well-known performance profiles procedure, that since then has become a standard way to compare algorithms. As evidence of this, as of September 2021, there were more than 4000 citations of the Dolan and Moré paper.

Its steady capacity in evolving and investing in research, brought JM to experiment with new ideas and challenges created by technological developments. An example of this is the NEOS server which introduces a completely new approach in solving optimization problems, based on computational servers and collaborative technologies. *The NEOS Server is a free internet-based service for solving numerical optimization problems. Hosted by the Wisconsin Institute for Discovery at the University of Wisconsin in Madison, the NEOS Server provides access to more than 60 state-of-the-art solvers in more than a dozen optimization categories. Solvers hosted by the University of Wisconsin in Madison run on distributed high-performance machines enabled by the HTCondor software; remote solvers run on machines at Arizona State University, the University of Klagenfurt in Austria, and the University of Minho in Portugal.*
Quoting From the 2003 Beale — Orchard-Hays Prize for excellence in computational optimization citation *" The NEOS Server has had a tremendous impact in the field of optimization, extending the reach of a wide selection of fundamental algorithms to a*

growing number of new applications areas. The influence of NEOS is such that in many applied fields the NEOS Server is synonymous with optimization". The project, started in 1998, is continuously evolving. Today NEOS is equipped with an online guide, several interfaces, and about 4000 jobs are submitted every day to the Server.

As further evolution in his "Synergistic Activities" is TAO.
TAO (Toolkit for Advanced Optimization) was the first toolkit for solving large-scale optimization problems on high-performance distributed architectures, ranging from high-end workstations to high-performance clusters. The main design goals were portability, performance, scalable parallelism, and an interface independent of the architecture. TAO solvers have been used to solve computational science problems in a wide variety of areas. TAO is now included as part of the PETSc (www.mcs.anl.gov/petsc) distribution.

In sum, what strikes me in Jorge is his intellectual honesty, his rigor and the depth of his scientific results, which have never been banal, never repetitive, and always presented with extreme clarity.

Before concluding, in addition to his scientific aptitude, I'm pleased to recall the way in which he deals with all the people he works with. He is exceptionally generous with his time and attention. He likes to share ideas and intuitions, and it doesn't matter if you are a Ph.D student or a famous scientist. Those who have had the privilege to collaborate with him have experienced his friendly manner and his capacity to keep the atmosphere relaxed, especially with his lively sense of humor.

This award is in recognition of the many contributions made by JM to the advancement of numerical optimization. But also in recognition of the way numerical analysis should be done: keeping in mind the applicability of the results without forgetting the methodological rigor.

With this, I praise the Rector and the colleagues of the department of Mathematics and Applications "R. Caccioppoli" for the decision that welcomes Jorge J. Moré in the University of Naples Federico II.

Thank you.

Gerardo Toraldo