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2021 International Statistical Institute Mahalanobis Award: A Tribute to Heleno Bolfarine

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Summary

The Government of India sponsors the Mahalanobis International Award, which, managed by the International Statistical Institute, is presented every other year at the International Statistical Institute World Statistics Congress. The Mahalanobis Award recognises an individual for lifetime achievements in statistics in a developing country or region. This article celebrates the 2021 winner, Prof. Heleno Bolfarine, who, unfortunately, passed away a few days before the award ceremony.

Key words: Mahalanobis Award; International Statistical Institute; Indian government; statistical capacity building; developing countries.

Introduction

The Mahalanobis International Award is sponsored by the Ministry of Statistics and Programme Implementation of the Government of India. The award recognises an individual for lifetime achievements in statistics in a developing country or region. It is expected that the award will have the potential to attract, inspire and motivate statisticians across the developing world to increase the quantity and improve the quality of their contributions to the cause of promotion and development of statistics and its applications. The award is presented biennially during the International Statistical Institute (ISI) World Statistics Congress (WSC). This article is a tribute to the 2021 recipient, Prof. Heleno Bolfarine (University of São Paulo, Brazil), who, unfortunately, passed away a few days before the award ceremony.

The award ceremony is usually held in person at the ISI WSC. However, in 2021, because of restrictions due to the COVID-19 pandemic, an in-person ceremony was hosted by the University of São Paulo, whereas the Mahalanobis session at the 63rd ISI WSC was held virtually.

This article starts with contributions by Fabrizio Ruggeri (ISI Vice President and Award Coordinator at the time) illustrating the spirit of the Mahalanobis Award, the selection process that led to the choice of Prof. Bolfarine and the ceremonies organised by the University of São Paulo and ISI. Then, Henrique Bolfarine (Heleno's son) and Jorge Luis Bazán present a short biography of Prof. Bolfarine and his statistical capacity-building activities, followed by personal memories by Reinaldo Arellano-Valle (2019 Mahalanobis Award recipient). More technical details on Prof. Bolfarine's scientific contributions are presented in the two final sections: Victor Hugo Lachos Davila presents the work on asymmetric models, and Mário de Castro discusses the work on measurement error models.

2021 Mahalanobis Award (Ruggeri)

The initiative by the Government of India serves the dual purpose of honouring Professor P. C. Mahalanobis for his lifetime contributions and achievements in statistics, and recognising and stimulating progress in statistics in developing countries. The achievements of the candidates will be considered under three main criteria and reflecting the spirit of Mahalanobis's lifetime work:

- academic leadership for developing countries,
- professional and official leadership for developing countries, and
- inspiration and capacity building within developing countries.

Some examples of contributions are as follows:

a innovative and concrete contributions to some field of application such as agriculture, economic development, education, health and industry;
b statistical capacity building at a national or regional level;
c improvements of national or regional statistical systems and/or infrastructure; and
d enrichment of statistical methodology.

The 2021 Committee, selected by the ISI Executive Committee, was chaired by Prof. Ingrid Kristine Glad (University of Oslo, Norway), and it had to choose from among a significant number of nominees, including many worthy of obtaining the award. The Committee selected Prof. Heleno Bolfarine (Figure 1), recognising his lifetime record of outstanding research contributions and academic leadership in the fields of statistical inference, error-in-variable models, calibration, reliability, distributions and sampling, prediction theory for finite populations and mixed models and regression analysis.

Furthermore, the Committee appreciated his lifelong and outstanding performance in capacity building through teaching and mentoring several generations of statisticians in Brazil and, more broadly, in South America, and his leadership and promotion of statistics and the statistics profession at both national and international levels, with special emphasis on South America. Heleno Bolfarine joins a list of distinguished researchers who obtained the award in the past, that is, C. R. Rao (India), Benjamin Kiregyera (Uganda), Isidoro P. David (Philippines), Pedro Morettin (Brazil), Victor Yohai (Argentina), Lamine Diop (Senegal), Carlos Jarque (Mexico), Rahul Mukherjee (India) and Reinaldo Arellano-Valle (Chile).

The Mahalanobis Award session at the virtual 63rd ISI WSC in July 2021 started with an introduction by ISI President John Bailer and a message from G.P. Samanta, Chief Statistician of India, read by Fabrizio Ruggeri. Those contributions were followed by images of the ceremony

Figure 1. *Prof. Heleno Bolfarine.*

held at the University of São Paulo, where Mr Suresh Reddy, Ambassador of India to Brazil, spoke about Prof. Mahalanobis's contributions to statistics and the Indian society and the achievement of Prof. Bolfarine. As mentioned, Prof. Bolfarine passed away a few days before the ceremony, so the Indian Ambassador presented the award to Mrs Ana Maria Mazanatti Bolfarine, Heleno's wife, who gave a very touching speech. The session ended with recorded contributions about the life and achievements of Prof. Bolfarine. The speakers in that session have summarised their talks in the following sections.

Capacity Building and Biography of Heleno Bolfarine (Bolfarine and Bazán)

In this work, we present a short biographical sketch and the academic achievements of Professor Heleno Bolfarine. His achievements justify, meritoriously, his receipt of the Mahalanobis International Award, sponsored by the Ministry of Statistics and Programme Implementation of the Government of India.

Short Bio

Heleno was born in 1949 in Cândido Mota, a small town almost 500 km from the capital of the state, São Paulo. He was the oldest from a family of 12 siblings. In Cândido Mota, Heleno showed a great interest in studying mathematics and playing soccer, in the local public school known as 'grupão' (big group) (Figure 2).

In 1972, Heleno received an undergraduate title in Mathematics from University 'Júlio de Mesquita', today known as São Paulo State University (UNESP) in the campus of Presidente Prudente, a city that is almost 560 km from São Paulo. During those years, he regularly visited the University of São Paulo's recently inaugurated Institute for Mathematics and Statistics (IME), where he attended summer courses in different areas. Later, Heleno enrolled in the master's programme in the recently established Statistics Department at IME, where the first master's and doctorate classes started in 1970. Heleno was supervised by Professor Pedro Alberto

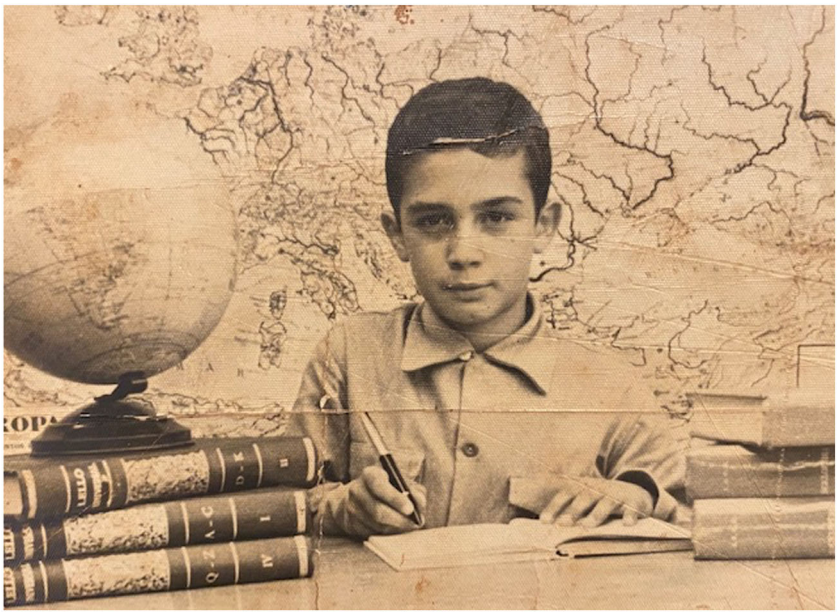

Figure 2. *Heleno Bolfarine at school.*

Morettin, also a Mahalanobis laureate, and would receive his master's degree in 1976. During his master's, Heleno met Josemar Rodrigues, one of his first colleagues and contributor, Professor Wilton Bussab (also a co-author), and Professor Carlos Alberto de Bragança Pereira (Carlinhos), who, at the time, had recently obtained his PhD degree under the supervision of Professor Debabrata Basu from Florida State University.

In 1975, Heleno married Ana Maria Mazanatti (Figure 3), whom he met in high school in his home town.

Figure 3. *Heleno Bolfarine and his wife.*

They had they first daughter, Mariana Bolfarine, in 1977. In the same year, Heleno joined the University of São Paulo's Statistics Department as an assistant professor. He moved with his family to the USA to pursue a graduate degree in Statistics at UC Berkeley. In this period, Heleno and Ana Maria would have two more children, Fernanda Bolfarine and Henrique Bolfarine (Figure 4).

Heleno completed his thesis 'On Combining Experts Assessments', under the supervision of Professor Richard Eugene Barlow. He would later return to Brazil in 1983, as doctoral assistant professor of Statistics at IME. Over the next years, Heleno would help modernise the Statistics Department, together with professors Josemar Rodrigues, Carlos A. Bragança and Jorge Achcar. In this period, he developed important work in the Theory for Finite Populations, in a joint effort with Josemar Rodrigues, Carlos A. Bragança and Professor Shelemyahu Zacks. He would publish in many peer-reviewed journals. In 1987, Heleno became fully tenured at IME. In this period, a book on measurement models from Fuller appeared, and he and Josemar Rodrigues started to investigate how they could contribute to the subject. This would result in several papers and contributions throughout the following years. Heleno also participated, directly and indirectly, in the foundation of many meetings and congresses. One of these meetings is the Escola de Modelos de Regressão (Figure 5), which is in its 17th edition; another one is EBEB, the Brazilian School of Bayesian Statistics.

In 1989, Heleno spent a year as a postdoc at the University of New York at Binghamton, where he would write his first book with co-author Shelemyahu Zacks, titled 'Prediction Theory for Finite Populations'. In 1990, Heleno lectured on a course in *Theory for Finite Populations* in the Pontificia Universidad Católica del Perú and would later advise many students from Perú. In 1992, Heleno became full professor of Statistics at IME. In 1994, Professor Reinaldo Arellano-Valle, a Mahalanobis laureate, was the second PhD professor Heleno advised. In his thesis, Reinaldo developed important results on elliptical distributions, and together, they would write various papers on asymmetric and error-in-variable models.

Figure 4. *Heleno Bolfarine and his children.*

Figure 5. *2015 Escola de Modelos de Regressão.*

Heleno would later receive several awards and recognitions, including the prestigious Jabuti Award for best book in Exact Sciences, Technology and Informatics in 2006 for the book 'Elements de Amostragem', co-authored with Wilton Bussab. Additionally, Heleno was elected Fellow of the Academy of Sciences of São Paulo in 2010 (Figure 6), obtained the lifetime achievement award from the Brazilian Association of Statistics in 2015 and, finally, received the prestigious Mahalanobis Award in 2021.

Figure 6. *Heleno Bolfarine elected Fellow of the Academy of Sciences of São Paulo in 2010.*

Academic Achievements

We prepared two databases (available upon request) to study Professor Bolfarine's academic performance. One database is based on PhD students he advised, which includes spatial information with the locations where they are currently teaching. The other is based on Professor Bolfarine's academic records, known as Curriculum Lattes (Brazilian government platform that records academic achievements), available at http://lattes.cnpq.br/8718672213653861. Further details are given in Bolfarine & Bazán (2021).

By considering the first database, Figure 7 shows the distribution of Professor Bolfarine's PhD students and the Department of Statistics where they are currently working. In total, he was advisor of 16 master's and 44 PhD students at the University of São Paulo. Professor Bolfarine advised 17 PhD students from Brazil, 8 from Chile, 14 from Peru, 2 from Argentina and 3 from Colombia. Currently, these researchers are located in 26 different departments of statistics, in important universities, in several countries in South America.

By considering the second database, we found that Professor Bolfarine's work encompassed diverse areas in the statistical sciences, including error-in-variable models, calibration, reliability, distributions and sampling, prediction theory for finite populations, mixed models and

Figure 7. *Map of America with the distributions of Professor Bolfarine's PhD students.*

regression analysis. Additionally, we note diverse contributions in statistical applications. Most of the papers follow a Bayesian approach.

Furthermore, Professor Bolfarine has published five books (three in Portuguese and two with Springer: *Prediction Theory for Finite Populations*, with Shelemyahu Zacks, and *Regression Models for the Comparison of Measurement Methods*, with Mario de Castro and Manuel Galea) and has published more than 337 refereed articles/book chapters in major academic journals with a wide network of collaborators resulting in more than 5 000 citations.

Professor Bolfarine not only advised students but also inspired generations of statisticians. Throughout his career, Professor Bolfarine helped to expand Statistical Science in Latin America. With extraordinary capacity, he created a research network that encourages collaborative interchange between different institutes. From the results we presented, we conclude that Professor Bolfarine excelled in research, teaching and scientific dissemination and has also led great efforts to promote statistics as a degree to pursue in South America. His career followed the principles and ideas of the great Professor Mahalanobis, and thus, he is worthy of the award inspired by him.

Heleno Bolfarine's Contributions Beyond Statistics (Arellano-Valle)

Professor Bolfarine (1949–2021) was not only an exceptional human being but also an exemplary husband, father and grandfather. In his professional life, he stood out for his academic and scientific leadership and also for his excellent performance in the teaching, training and guidance of several generations of Latin American statisticians. He was a great teacher and a first-rate researcher, who inspired many students and academicians, and he won the friendship and admiration of many people for his nobility and enormous generosity. He is, without a doubt, an example worth following both personally and professionally, and a source of inspiration for the statisticians of our region. His contribution to the development of statistics in South America is perhaps one of the most relevant in the last three decades. His legacy is broad and substantial, reflected in more than 240 publications and in the training of more than 40 doctoral students of different nationalities, most of whom today hold important academic positions within the main universities of the region.

He also was an outstanding and very versatile teacher and researcher, and his scientific contributions cover practically all areas of statistics. In fact, he was one of the two Brazilian statisticians who achieved the category 1A defined by the Brazilian National Research Council (CNPq), and from 2012, he was a full member of the São Paulo State Academy of Sciences.

I was able to personally meet Professor Bolfarine between 1991 and 1994, while I was doing my PhD in Statistics at the University of São Paulo of Brazil, because I approached him to ask him to be my thesis supervisor. I remember perfectly that day when he handed me an article by Lange *et al*. (1989), which proposed the *t*-model as a robust alternative to the classic normal model. From there, we arrived at elliptical models, thus opening a wide field of research in our region, which continued later from skew-elliptical models. That was the starting point of a long and very pleasant period of friendship and scientific collaboration, which was also joined by Professor Pilar Iglesias, whose premature death not only affected us a lot personally, but also in our scientific work. From there, many scientific collaboration projects were produced between Brazil and Chile, generating several research visits in both Brazil and Chile, various master and doctoral thesis projects, innumerable participations in regional and international scientific meetings, and many joint publications in different statistical journals. A list of scientific collaboration with Professor Bolfarine in supervision of PhD thesis and joint publications with him is available in Arellano-Valle (2021). Obviously, the most significant thing was the close bond of friendship that was generated with him and his charming wife, our appreciated

Ana María Mazanatti, where we also had the presence of our dear friends Pilar Iglesias, Marcia Branco, Rosangela Loschi and Marc Genton. Many wonderful memories, in both Brazil and Chile, and in other countries of the world, were produced from the diffusion of our scientific production, and all this reinforced by our close friendship (Figure 8). Always, when talking with him, there was empathy and personal trust, and ideas flew naturally and spontaneously.

There is no doubt that his contribution to the advancement of statistics in our region fully reflects the true spirit of the Mahalanobis Prize.

Thank you, Professor Bolfarine, for giving your whole life to statistics with passion, generosity and greatness!

Heleno Bolfarine's Contributions in Asymmetric Models (Lachos)

It is a pleasure to write this note in honour of my PhD advisor, Professor Bolfarine. He was always my mentor and guide when I had big decision to make in my academic career, and I am eternally grateful to him for trusting me. I met Professor Bolfarine for the first time during my master's thesis defence in State University of Campinas in 2002. Our joint collaboration started in 2003, after discussing the topic of my thesis with my co-advisor, Professor Reinaldo Arellano-Valle—the 2019 ISI Mahalanobis Award recipient. Currently, Professor Bolfarine is my most significant collaborator with 21 joint publications in refereed journals; some of these publications were the product of co-advising PhD students (five in total) in the Department of Statistics at the University of São Paulo.

I have divided his main contribution related to asymmetric models into four areas: (i) linear mixed models (topic of my PhD thesis), (ii) measurement error models, (iii) finite mixtures of distributions and (iv) binary regression. I will avoid mathematical formulae in this note, but I refer the interested readers to Lachos (2021).

Figure 8. *A scientific meeting or a scientists' meeting?*

The Skew-normal Linear Mixed Model

In general, a linear mixed model assumes that the random error and the random effects follow jointly a normal distribution. In a seminal paper by Arellano-Valle *et al*. (2005a), we replace the Gaussian assumption by the skew-normal distribution, mainly motivated by the increasing interest to consider more flexible distributions in statistical models. For the proposed skew-normal linear mixed model, an expectation–maximisation-type algorithm is proposed for maximum likelihood estimation and interesting properties are derived. So far, this paper has around 230 citations, which is almost double the number of citations received by the Bayesian version of this paper published by the same authors in 2007 (Arellano-Valle *et al*., 2007). In fact, both papers are the most cited papers of Professor Bolfarine according to Google Scholar. Further publications related to these topics include Lachos *et al*. (2007) published in a special issue in skew distributions and more recently by Ferreira *et al*. (2021), where the scale mixtures of skew-normal distribution were used to model the random terms. Inferential procedures and model evaluation tools related to the skew-normal linear mixed model and its extensions have been included in the R library *skewlmm* available at CRAN.

The Skew-normal Measurement Error Model

Measurement error models are models with at least one independent variable that is measured with error. In general, a simple measurement error model assumes that the random terms follow a normal distribution. In the same way, in a seminal paper, Arellano-Valle *et al*. (2005b) proposed the skew-normal measurement error model by replacing the normal assumption by the multivariate skew-normal distribution (Lachos, 2021). For this novel model, an expectation–maximisation-type algorithm is proposed for maximum likelihood estimation. The Bayesian approach is also discussed in the same paper. Further publications related to this topics include Lachos & Bolfarine (2006), where a skew link for binary regression with measurement errors is proposed, and Lachos *et al*. (2010), where the multivariate measurement error model based on the scale mixtures of skew-normal distribution is proposed and several elegant properties are derived.

Finite Mixtures of Skew Distributions

A finite mixture model is a convex combination of two or more probability density functions of different forms, in particular the skew-normal distribution could be considered. In this context, Cabral *et al*. (2008) developed a Bayesian approach of finite mixture using the skew Student-*t*-normal distribution. Actually, this paper motivated me to start in this area of research, and so far, I have written around 10 papers related to this topic, including a book published by Springer in 2018. From 2014 to 2018, I co-advised Bolfarine's PhD student Luis Benites Sanchez with the thesis titled 'Finite Mixtures of Regression Models'.

Binary Regression with Skew-link

This idea considers the cumulative density function of the skew-normal distribution instead of the usual probit link in binary regression. Some important contributions of Prof. Bolfarine in this topic are (i) Lachos & Bolfarine (2006), where a skew binary regression with measurement errors is proposed, and (ii) Bazán *et al*. (2006), where the skew-probit link for item response theory is proposed. The latter paper, published in Bayesian Analysis, has around 120 citations according to Google Scholar. I would like to say 'Thank you Professor Bazán for the initiative to nominate Prof. Bolfarine for this well-deserved award'.

Prof. Bolfarine was an outstanding scientist who made significant novel contributions in Latin America. There is no doubt that Prof. Bolfarine is in the top percentage of scientists with a remarkable influence, and his statistical expertise has greatly benefited the scientific community in Latin America and abroad. Thank you Prof. Heleno Bolfarine for the enormous contribution to my academic career and inspiring young researchers.

Measurement Error Models (de Castro)

This note gives a short account of Prof. Bolfarine's contributions to the measurement error models literature (see also de Castro, 2021). The main source is the Web of Science database (© 2021 Clarivate).

A measurement error model is a kind of regression model with applications in areas such as analytical chemistry, astrophysics, biology, economics, engineering, epidemiology and medicine. Adcock (1877, 1878) are regarded as the pioneering works on such models. Error-in-variable model, orthogonal regression, Deming regression, bivariate least squares, total least squares, regression with errors in both axes and regression with errors in both variables are also used to refer to measurement error models.

Prof. Bolfarine's contributions comprise 81 publications (journal papers and books). Publication dates span from 1990 to 2021 (three decades). Authorship of the publications includes more than 20 PhD students advised by him. His contributions cover theory, methodology and applications.

His first contribution is a paper on superpopulation models under a Bayesian approach (Bolfarine & Rodrigues, 1990), whereas Hokama *et al*. (2021) is the last one. His work on measurement error models also comprises other areas, as can be seen in Arellano-Valle *et al*. (2005a), Mizoi *et al*. (2007), Casanova *et al*. (2010) and Bolfarine *et al*. (2020), to name just a few.

A Final Comment

All the authors have had the opportunity to share enjoyable moments with Prof. Bolfarine, even those who never worked with him (Fabrizio Ruggeri), and are very grateful to the Editors-in-Chief of ISR for the opportunity to pay a tribute to him.

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