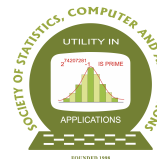


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PREFACE

Professor Bikas Kumar Sinha, who is the Leader of the Guest Editors Panel for this special issue of “Statistics and Applications”, invited me to write a preface for this special issue of the journal to be released in memory of Late Professor C. R. Rao. I am honored to be a part of the group as I was a student of Professor C. R. Rao in the very first batch of M. Stat. program at the Indian Statistical Institute, Calcutta (now Kolkata) during the years 1960-62 and was his colleague at the Indian Statistical Institute, New Delhi during the years 1976-79 before he left for USA. The contributors to this volume are well known specialists in their chosen branches or areas of statistics and their contributions reflect the areas to which Professor C. R. Rao has made significant contributions.

Calyampudi Radhakrishna Rao (aka) as C. R. Rao needs no introduction to statisticians, mathematicians, scientists or communication engineers. In the volume “Glimpses of Indian Statistical Heritage”, edited by J. K. Ghosh, S. K. Mitra and K. R. Parthasarathy (Wiley Eastern Limited, New Delhi (1992)), who are themselves distinguished statisticians and probabilists, C. R. Rao wrote an autobiographical account highlighting the circumstances and influences that led him to a career in statistics and probability. He titled his autobiographical account as “Statistics as a Last Resort”. It is appropriate to mention that he came into statistics by chance. By spending a life time putting chance to work, he has built an inspiring legacy.

C. R. Rao was born on September 10, 1920 in Huvvina Hadagalli, then in the integrated Madras province and now in the state of Karnataka. His father C. Doraiswamy Naidu was an Inspector of Police and his mother was A. Laxmikanthamma and Rao grew up in a family environment. Rao was admitted in class 2 (second grade) in 1925 when he was only 5 years old. Since Rao’s father was an inspector of police, the job required the family to move from place to place once in every two or three years.

Rao completed his classes 2 and 3 in a town named Gudur, classes 4 and 5 in Nuzvid and first and second forms in Nandigama all in the present state of Andhra Pradesh. At this stage, his father retired and decided to settle down in Visakhapatnam. Rao finished his high school and joined the Andhra University for obtaining his first college degree in Visakhapatnam. Rao’s early childhood involved frequent moves from one place to another but that did not affect his studies . His parents provided him guidance and environment conducive to studying and instilled in him work ethics that endowed him to achieve higher

goals in life. As a student, his ambition was to keep on learning. He said that he has inherited his father's analytical ability and his mother's zeal and industry.

Rao said that his mother was instrumental in instilling a sense of discipline in him. In his book on "Statistics and Truth: Putting Chance to work", Rao acknowledges her contribution to his life with the dedication "For instilling in me the quest for knowledge, I owe to my mother, A. Laxmikanthamma, who, in my younger days, woke me up every day at four in the morning and lit the oil lamp for me to study in the quiet hours of the morning when the mind is fresh".

Rao graduated with the B.A. (Hons) degree in Mathematics at the Andhra University in Vizag. It was at the Andhra University as a seventeen year old that Rao developed research interest in mathematics. His most inspiring teacher was a Cambridge trained mathematician Dr. Vommi Ramaswami who was the head of the Department of Mathematics. Rao finished the B.A. (Hons) course at the age of 19 and wanted to pursue a research career in mathematics. With a first class and first rank in B.A. (Hons) degree, Rao thought he would qualify for a scholarship for doing research in mathematics. He did not get the scholarship for bureaucratic reasons. He was in search of a job and saw an advertisement for a mathematician for the army survey unit. He went to Calcutta to appear for an interview for the job but was not successful. During his stay in Calcutta, he met one Subramanian who was employed in Bombay but had been sent to Calcutta for training in statistics at the Indian statistical institute (ISI). Rao joined ISI at his suggestion. As they say "Rest is history".

Rao obtained his Ph.D. degree from the Cambridge University and became a professor at ISI at the age of 29 years. After retiring from ISI in 1980, he moved to USA and worked for another forty three years and was a research professor at the University of Buffalo in USA till the time of his passing away. He received several awards including the Bhatnagar award, India Science award from the Government of India, National Medal of Science from USA and elected as Fellow of several academies in India and abroad. He received 39 honorary doctorates from universities in India and abroad. Several students received Ph.D. under his guidance.

As they say "Statistics is the poetry of sciences". Statistics is the soul of scientific inquiry. It is applied by researchers across a spectrum of science, engineering, business, technology, medical, government and financial settings to name some. These applications lead ultimately to tangible benefits that improve the well being of humanity. With the increasing role of information technology, the society has been inundated by a data deluge and statisticians are the society's experts for extracting usable information from the mass of noise in those data sets. Statistics and statisticians make the science better. It is an invisible science. It is said that "A physicist solves a problem in physics using the available knowledge in physics, a chemist does the same thing in chemistry, so also a biologist and an engineer. There is nothing like a statistical problem a statistician is trying to solve with the available knowledge of statistics. His or her job is to help the scientists to solve problems in their discipline by applying available statistical methodology, but more often by developing

appropriate new statistical methodology”.

C. R. Rao was among the world wide leaders in statistical science over the last several decades.

Rao’s career in statistics is dotted with remarkable achievements. The first result in statistics to bear Rao’s name was proven by him, while still at ISI, at the age of 25 and came to be known as the Cramer-Rao inequality. In his remarkable 1945 paper published in the *Bulletin of the Calcutta Mathematical Society*, Rao demonstrated three fundamental results that paved the way for the modern field of statistics and provided statistical tools heavily used in science. The first now known as the Cramer-Rao lower bound provides a means of knowing when a method for estimating a quantity is as good as any method can be. The second result named as the Rao-Blackwell theorem provides a means of transforming an estimate into a better, in fact optimal, estimate. Together, these results form a foundation on which much of statistics is built. And the third result provides insights that pioneered a new interdisciplinary field that has come to be known as *information geometry*. Combined, these results help scientists extract information from data efficiently. The monumental work by Rao has not only revolutionized statistical thinking in its time but also continues to exert influence on human understanding of sciences across wide spectrum of disciplines according to the Chair of the International Prize in Statistics which Rao received . Rao made distinct and extensive contributions to several branches of the subject of statistics and its applications leading to efficient methods of statistical analysis.

Once a doctor examining him for some stomach ailment told Rao that the food for each individual in stomach would be a variable and normally distributed..(a term familiar to the statisticians). Rao told “the doctor was trying to give me a lecture in statistics, which I had been teaching to my students for over 25 years ...(at that time).” Rao lost his baggage during one of his international travels. One of the agents of the airlines called Rao next day and said “Good News Mr. Cramer Rao, we found your baggage” thinking that Cramer Rao is Rao’s name but it is the lower bound named after him and Professor Cramer who have discovered the result.

In multivariate analysis, one has to deal with extraction of information from a large number of measurements made on each sample unit. Not all measurements carry independent information. It is possible that a subset of measurements may lead to procedures which are more efficient than using the whole set of measurements. Rao developed a test to ascertain whether or not the information contained in a subset is the same as that given in the complete set. He also developed a method for studying clustering and other inter-relationships among individuals or populations. Using general diversity measures applicable to both qualitative and quantitative data, the method of analysis of diversity was developed by Rao for which he introduced the concept of quadratic entropy in the analysis of diversity.

Combinatorial arrangements known as orthogonal arrays were introduced by Rao for use in the design of experiments. These arrangements are widely used in multi-factorial experiments to determine the optimum combinations of factors to solve industrial problems.

These have also applications in coding theory. An important result of practical interest resulting from this novel approach is the Hamming-Rao bound associated with orthogonal arrays.

Rao's work was done in India and his intellect shaped statistics worldwide. He was among the worldwide leaders in statistical science. His research, scholarship and professional service had a profound influence in the theory and applications of statistics and are incorporated into standard references for statistical study and practice.

When Rao joined the ISI in early forties, statistics was not considered as an independent subject and no university offered courses at the Masters level. Rao developed numerous courses in statistics over the years which were later converted into bachelor's and masters degree at ISI when ISI was declared as an Institute of National Importance by an act of Parliament in 1959. Rao also initiated the Ph.D. program in theoretical statistics and probability. Rao guided the research work of over fifty students for Ph.D.

As the Head of Research and Training School at the ISI, Rao developed a variety of courses to train statisticians to work in different applied areas. Rao established research units in ISI to work on special projects in subjects such as economics, sociology, psychology, genetics, anthropology, geology and related areas. The idea of establishing these applied research units is to provide interaction between statisticians and scientists to promote the application of statistical methods in research in other areas and to develop new statistical methods motivated by real problems.

Pandit Jawaharlal Nehru, who was the Prime Minister at that time, was greatly interested in development of statistics. He visited ISI a number of times at the invitation of Professor Mahalanobis and Rao had the opportunity of discussing with him the national statistical system and training of statisticians to work in state statistical bureaus. Nehru moved a resolution in the parliament in 1959 declaring ISI as an Institute of National Importance.

Rao was the author of 14 books. Two of his books were translated into several European, Japanese and Chinese languages. Rao received 39 honorary doctorates from universities in 19 countries spanning over all continents. Rao received several awards and medals. Some of them are the National Medal of Science, the highest award given to a scientist in USA in 2002, India Science award in 2009, the highest award given to a scientist in India and the Guy Medal in Gold from the Royal Statistical Society in 2011, the highest award given to a statistician in UK.

Rao has received the Bhatnagar award in 1963 and International Mahalanobis prize in 2003 for lifetime achievement in statistics and the promotion of best statistical practice from the International Statistical Institute. The Ministry of Statistics and Program Implementation (MOSPI), Government of India has instituted a National award in honor of C. R. Rao. He was elected as a Fellow of the Royal Society (FRS) in UK, Fellow of the Indian National Science Academy (FNA), Fellow of the Indian Academy of Sciences (FASc), Fellow of the National Academy of Sciences (FNASc) in India, and Fellow of the Third world Academy of Sciences besides several others. Rao celebrated his 102nd birthday on September 10, 2022.

C. R. Rao, a professor whose work more than 75 years ago continued to exert a profound influence on science, has been awarded the 2023 International Statistics Prize in his 102nd year. Awarded biennially at the World Congress of International Statistical Institute, the International Statistics Prize in Statistics is managed by a foundation consisting of five major statistical societies: American Statistical Association, Institute of Mathematical Statistics, International Biometric Society, International Statistical Institute and the Royal Statistical Society.

A scientist visiting ISI from the former Soviet Union went to meet Dr. Rao (as he is known to all the workers at ISI) when he was in Calcutta at his residence. He was told that Rao was repairing his car. He met him in the office room later when Dr. Rao was with his students, then saw him playing badminton outdoors in the evening and had dinner with him in the night. The scientist remarked that “I have seen the mechanic, the athlete, the scholar and the perfect host, all in one day.” He was an enthusiastic photographer and was very much interested in spreading dance forms such as Kuchipudi.

I have also graduated from the Department of Mathematics from the Andhra University in 1960 as Professor C. R. Rao and later joined ISI as a student during the years 1960-62 for my Masters program in Statistics. I met Professor Rao as a student at the age of 17 and attended courses given by him. I was his colleague at the Indian Statistical Institute, New Delhi during the years 1976-79 and later joined the CR Rao Advanced Institute of Mathematics, Statistics and Computer science, Hyderabad as Ramanujan chair Professor at his invitation. I had the privilege of participating in a Zoom meeting honoring him across continents during his centenary year. ISI Retired Employees Association has released a book entitled “A Tribute to the Legend of C. R. Rao, The Centenary Volume”. Professor T. J. Rao, who is a well-known survey sampling expert, and I were both students of Professor C. R. Rao at the ISI and all the three of us are alumni from the Department of Mathematics at the Andhra University, Vizag.

Rao passed away on August 22, 2023 at the age of 102 just about two weeks before his 103rd birthday on September 10, 2023. He was a Research Professor at the University at Buffalo, USA till the last day. India has lost a distinguished statistician and a great scientist.

I am happy to note that the journal “Statistics and Applications” has taken the initiative to bring out this special issue in memory of Late Professor C. R. Rao and happy to be a part of this activity to pay my homage as his student, his colleague and his admirer.”

B. L. S. Prakasa Rao
Hyderabad, India

August 12, 2024