

Calyampudi Radhakrishna Rao (1920–2023)

Around seven decades ago, a passenger travelling to Calcutta by the Madras–Howrah Mail was asked what he did for a living. Perhaps, feeling that an accurate reply would not be understood, he seems to have replied: ‘I work in a school and I am the Head Master of the school’. The school referred to is the world-famous Research and Training School (RTS) of the Indian Statistical Institute (ISI), and the unassuming passenger was none other than the legend Professor C. R. Rao, who was indeed the Head of the School for almost quarter of a century.

Calyampudi Radhakrishna Rao, well-known as C. R. Rao (and Dr Rao to his students) was born on 10 September 1920 in Huvanna Hadagali, now in Karnataka, India. He passed away on 22 August 2023, 18 days before his 103rd birth anniversary, leaving a big void for the statistical fraternity of the world. Rao’s ‘work over 75 years which continues to exert a profound influence on science has been awarded the prestigious 2023 International Prize in Statistics’, considered as the Nobel equivalent in statistics.

Rao studied in various schools in Andhra Pradesh, moving along with his father, an inspector of police. In the elementary school, when he was six, his teacher would ask him to recite multiplication tables and the other students would repeat after him. While playing *Gilli Danda* with his friends, Rao used to correctly guess the distance (runs, as measured by the length of the stick), showing his prowess in ‘estimation theory’ at a young age itself.

At the age of 16, the Mrs A. V. N. College, Visakhapatnam magazine had a caption under his photo saying ‘he has had the unique distinction of knocking off the most coveted prizes in every class until now. We hope he will continue to maintain the high efficiency of his mental and academic facilities in the years to come’. And indeed he did so with 14 books (two of them translated into 7 and 6 languages respectively), 470-plus research papers, 51 Ph.D. students, 44 edited volumes of *Handbook of Statistics* and 39 honorary doctorates from universities in 19 countries spanning 6 continents.

Rao obtained his B.A. (Hons), three-year postgraduate degree in mathematics, a course popular among bright students in South Indian universities, from Andhra University in 1940, and M.A. degree in 1941 by efflux of time, with a first class

first. His sole application for a research scholarship was rejected on officious grounds. (After some years, the same University would confer on him an honorary Doctorate.) Looking for a job, Rao went to Calcutta and appeared at an interview for the job of an Army Mathematician. Being under-aged, he was not offered the job in spite of his excellent qualifications. In the hotel where he was staying, Rao met a person who was visiting Calcutta from Bombay to be trained at the ISI. He took Rao to



ISI, which was just a small laboratory in Presidency College run by P. C. Mahalanobis (PCM). Impressed by the work being carried out there, Rao joined as a statistical trainee. Just then PCM started the M.A. course in statistics and Rao was one of the first five students; he got his M.A. in 1943, again with a first class first. Soon after, he joined ISI as a technical apprentice and started working in the areas of Design of Experiments and Multivariate Analysis having been inspired by R. C. Bose, K. R. Nair and S. N. Roy who were senior scholars at the Institute. While he was a Superintending Statistician (1944–48), Rao collaborated with the anthropologist D. N. Majumdar and analysed the anthropometric data based on a survey of the United Provinces using the concept of PCM’s D^2 , a measure of distance between two populations. PCM deputed him to Cambridge to work at the Museum of Archaeology and Ethnology on skeletal remains from Africa collected by them. Simultaneously, he worked with R. A. Fisher and got a Ph.D. from Cambridge University, UK, in 1948. Later, by peer review, Rao was given a

Sc.D. by Cambridge University. On his return, he became the Professor and Head of RTS and held important positions as Director and Secretary of ISI (1972–76, an unsatisfactory period for Rao when he decided to move to the Delhi campus), Jawaharlal Nehru Professor (1976–84), and National Professor (1987–92). Throughout his tenure, world-class research facilities were made available at ISI. Rao arranged long- and short-time visits by renowned experts, organized lecture series and encouraged publication of monographs. Thus this period came to be known as the ‘golden period’ of ISI.

Since the post-retirement scenario in India was not much conducive for continuing research, Rao moved to USA and continued research with renewed vigour, first in the University of Pittsburgh and later in Pennsylvania State University, where he was Director at Center for Multivariate Analysis as well as Eberly (Chair) Professor of Statistics. He was a Research Professor at the University at Buffalo, until recently.

Rao was a Fellow of the Royal Society; National Academy of Sciences, USA and Third World Academy of Sciences among others. Kings College, Cambridge gave him an exclusive Honorary Life Membership (given to only eleven persons at any time).

When Rao received the Shanti Swarup Bhatnagar Award (1963) during the China–India war, he donated the entire prize money to the Prime Minister’s National Defence Fund saying that ‘...I greatly appreciate the cash award you have given me. No doubt, for a poorly paid scientist, like myself, a monetary award is welcome. But now, with the unprovoked Chinese invasion on, I feel that the country’s need is greater than that of an individual scientist ...’. The other awards Rao received include Padma Vibhushan – the second highest civilian award by the Government of India, International Mahalanobis Award, India Science Award, Genome Valley Excellence Award and National Medal of Science, USA. The Royal Statistical Society, UK, honoured him with the Guy Medal in Gold, given for the first time in 118 years to an Asian.

The citation of the International Statistical Prize says; ‘*In his remarkable 1945 paper published in the Bulletin of the Calcutta Mathematical Society, Calyampudi Radhakrishna (C.R.) Rao demonstrated three fundamental results that paved the way for*

the modern field of Statistics and provided statistical tools heavily used in science today. These are “Cramér–Rao lower bound”, Rao–Blackwell Theorem and the third result now flourished as “information geometry”. Rao’s contributions have been recorded in detail by several authors. Some of his fundamental contributions had a great impact in furthering research. We quote him: *‘I have seen Statistics grow into a strong independent field of study based on mathematical, and more recently computational tools...., Statistics is the Science of learning from data. Today is the age of data revolution. Therefore, there is need for Statistics, both in terms of training in Statistics to help analyze and interpret the data, and in terms of research to answer new questions arising from the data.’*

Besides Mathematical Statistics, Applied Statistics, including Sampling Theory and Experimental Designs, Rao has contributed to Official Statistics and has an influence in Financial Statistics. It may be pointed out that one of his first papers on the Design of Experiments was published in this journal, *Current Science* (Rao, C. R., Quasi-Latin square in experimental arrangements, 1943, **12**, 322–323). His work on Orthogonal Arrays was termed as a ‘New Mantra’ and applied in the US industries. Taguchi visited ISI and took the technique to Japan, and popularized it in Japanese industries. Rao’s paradox in sample surveys, as termed by D. R. Cox, refers to the situation that ‘if one wants to use the likelihood principle, it pays to throw away part of the observed data’.

In the sixties, during RTS tea-club sessions, Rao used to say, if you need a grant, use the terms ‘signal and noise’. Little did he know then that his CRLB of the 1945 breakthrough paper is being quoted in a number of papers on Signal Processing, Engineering Sciences, and in a host of other areas, such as pixel-array detectors, spectroscopic measurements, PET detector designs, SBP methods for 3D event positioning and quantum physics.

The other breakthrough work popularized as ‘Rao–Blackwellization’ (RB) is abund-

antly used in Sampling Theory, Dynamic Bayesian Networks, Monte Carlo Methods, Cross Validation and Non Parametric Bootstrap, particle filtering, stereology, data compression Rao–Blackwellized Gaussian smoothing, Rao–Blackwellized Parts-Constellation Tracker and a host of other areas.

Surprisingly, RB had applications in basketball ratings as Rao–Blackwellized field goal percentage estimator (RB-FG%). It can be applied for cricket/soccer ratings of players. Another concept called Rao–Blackwellized WhatsApp (RB WA) has been floated too.

Rao solved the problem raised by Ragnar Frisch applying his score test known to econometricians as Lagrange multiplier test. He was the founding President of the Indian Econometric Society. He was honoured with the establishment of an institute in the University of Hyderabad (UoH), named after him as C.R. Rao Advanced Institute of Mathematics, Statistics and Computer Science (CRRAO AIMSCS). In this Institute there is a C.R. Rao Gallery, designed by his daughter, Dr Tejaswini Rao, which was inaugurated by the Nobel laureate Venkataraman Ramakrishnan in 2013.

Two innovative ideas of Rao are Statistics Olympiad and Statistics Museum. During my tenure as Adjunct Professor at CRRAO AIMSCS, Rao during his winter visits to the Institute, discussed the possibility of Statistics Olympiad like in Mathematics/Physics. His idea was to identify talented students at the school level itself with an aptitude for numbers and ability for statistical reasoning, and encourage them to study and take up statistics as a career. The First Statistics Olympiad test and the marking system started in 2009 were successful and acclaimed by the Royal Statistical Society as well. The other brainchild of Rao is the Statistics Museum for which the foundation stone was laid by Dr A. P. J. Abdul Kalam, the then President of India, in the land given by the UoH. His idea was to maintain Facit machines, punch cards, other sorting equipment, crop-cutting tools, graph papers, square sheets, logarithm tables, etc. for the future generations. It is

expected that UoH, CRR AIMSCS, the Government of India and well-wishers would make Rao’s dream come true.

Rao could teach at any level. For the junior officers of the International Statistical Education Centre at ISI for which he was the Chairman, Rao used to make his lecture simple and easy to understand. For degree students, he would call one of us to the board and make every one participate in the lecture. He devised the course structure so as to include theory as well as practicals. During the fifties when National Sample Survey started, Rao participated in all stages of data collection. Thus he believed in first-hand experience and sent us to field visits in Giridih, then in Bihar for socio-economic surveys and crop-cutting experiments. He would also send students to Central Statistical Organization for training in Official Statistics. Rao was indeed a great teacher.

His hobbies included photography, badminton and writing humorous stories.

We remember him as a statistician ‘who paved the way for the modern field of statistics’,

We remember him as a ‘prophet of a better age’,

We remember him as a champion of ‘pioneering work towards statistical systems of developing countries’,

We remember him as a ‘scientist’s scientist’,

We remember him as a great teacher, and the list goes on ...

Let us remember Rao as a legend who ‘left us an example of life filled with love, dedication and duty, and of life dedicated to action with knowledge and activity with achievement.’

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