Obituary
Roland Lvovich Dobrushin, 1929 – 1995

Roland Lvovich Dobrushin, an outstanding scientist in the domain of probability theory, information theory and mathematical physics, died of cancer in Moscow, on November 12, 1995, at the age of 66. Dobrushin's premature decease is a tremendous loss to Russian and world science.

Dobrushin was born on July 20, 1929 in Leningrad (St.-Petersburg). In early childhood he lost his father; his mother died when he was still a schoolboy. In 1936, after his father's death, the family moved to Moscow. In 1947, on leaving school, Dobrushin entered the Mechanico-Mathematical Department of Moscow University and after graduating from it did postgraduate studies. Then, from 1955 to 1965, he worked at the Probability Theory Section of the Mechanico-Mathematical Department of Moscow University, and since 1967 until his demise was Head of the Multicomponent Random Systems Laboratory, within the Institute for Information Transmission Problems of the Russian Academy of Sciences (the Academy of Sciences of the USSR). Since 1967 Dobrushin was a Professor in the Electromagnetic Waves Section of the Moscow Physics Technologies Institute and since 1991 he was a Professor in the Probability Theory Section at Moscow University as well. In 1955 Dobrushin presented his candidate's thesis, and in 1962 he took his Doctor's degree.

Even as a schoolboy Dobrushin conceived an interest in mathematics and participated in school mathematical contests where he won a number of prizes. While at the University Dobrushin was an active member of E.B. Dynkin's seminar[1]. On A.N. Kolmogorov's recommendation, and with his active support, he joined the postgraduate courses at the probability theory chair of the Moscow University.

Dobrushin's first published work was his paper on the regularity conditions for homogeneous Markov processes with countable numbers of states. This article was the first in a series of Dobrushin's publications devoted to the study of Markov chains. His findings turned out to be of great interest. In particular, he gave a complete description of Markov chains with a countable number of states and with fixed transition probabilities (some additional conditions being imposed on these probabilities) and was the first to construct an example of a countable homogeneous Markov chain, all the states of which are instantaneous.

But his principal contribution to this domain concerns the limit theorems for Markov chains and in particular the central limit theorem for inhomogeneous Markov chains (it is precisely those problems that he was working on in his Ph.D). Dobrushin introduced the important notion of the coefficient of ergodicity of an inhomogeneous Markov chain, and used it to give a sufficient condition for the validity of the central limit theorem for an inhomogeneous Markov chain. In a sense, this result cannot be improved. It generalizes the classic results of A.A. Markov as well as the results of S.N. Bernstein, Yu.V. Linnik, and N.A. Sapogov.

It is worth mentioning that in some earlier publications on the limit theorems for homogeneous two-state Markov chains Dobrushin described all possible limit distributions for the normalized quantities ξ_n – the number of visits of a fixed state during the first n steps – under different assumptions about the behavior of transition probabilities as $n \to \infty$ and limit theorems for the simple random walk on a line.

In one of his first papers (1958) on radiolocation Dobrushin was concerned with the asymptotic behavior of the minimal allowed value of the "signal/noise" ratio, under which the identification of the signal against the background of noise is still possible, with given probabilities of false alarm and the correct identification. Thus even Dobrushin's initial steps in science showed the most prominent feature of his whole scientific activity – a constant drive at getting the most general results combined with a keen interest in what might seem to be very specific applied problems. The methods of solving such specific problems proposed by Dobrushin proved to be very useful in tackling a great many other problems and sometimes gave rise to quite new directions of research.

[1] A "seminar" in this context is essentially a research group, with weekly presentations playing a central role.

In the fifties, information theory was a fresh and attractive field for Soviet mathematicians. They felt that Shannon's results were much deeper and more general than they were assumed to be. It encouraged Dobrushin, together with a group of other young and talented mathematicians to start working on the mathematical foundations of information theory. Initially, their efforts were directed by Kolmogorov.

Dobrushin was interested in finding the most general and natural conditions on the channel and source for which the Shannon theorems would be valid. He gave an elegant and probabilistically crystal-clear formulation of those conditions in terms of information stability. Let (X_n, Y_n) be a sequence of pairs of random variables. Denote by I_n the Shannon mutual information of X_n and Y_n, and let a_n be the logarithm of the Radon-Nikodim derivative of the joint distribution of X_n, Y_n with respect to the product of their marginals. According to Dobrushin, a sequence (X_n, Y_n) is said to be informationally stable if $I_n < \infty$ for all finite n and $(a_n/I_n) \to 1$ in probability as $n \to \infty$. Dobrushin showed that the channel coding theorem holds if there is information stability of admissible pairs (X_n, Y_n) of n successive channel inputs (X_n) and n successive channel outputs (Y_n). Analogously, the source coding theorem holds if there is information stability of admissible pairs (X_n, Y_n), where (X_n) is a sequence of n successive source outputs and (Y_n) is its length-n representation sequence with respect to the fidelity criterion.

The problem of expressing the optimal error probability $e(R, n)$ and the error exponent

$$E(R) = -\lim_{n\to\infty} \frac{\ln e(R, n)}{n}$$

as functions of rate R and code length n was in the focus of information theory. Generalizing P. Elias' result for the BSC, Dobrushin found $E(R)$ and the asymptotic expression for $\ln e(R, n)$ for $R_{\text{crit}} < R < C$ and the bounds on $E(R)$ for $R < R_{\text{crit}}$ for a memoryless channel having each row (column) of the channel transition matrix as a permutation of elements of any other row (column). He proved the existence of group codes such that error probabilities for them asymptotically coincide with $e(R, N)$ for discrete symmetric (not necessarily binary) memoryless channels (DSC) when $R_{\text{crit}} < R$. For the same DSC when $R_{\text{crit}} < R$, Dobrushin proved that the error exponent $E(R)$ is the same with and without feedback.

In practice, the channel transition probabilities (as well as the distributions of source sequences) usually are not known precisely, and it is possible to assume only that they belong to a certain specified class of distributions G_n (F_n, for the source coding problem). Thus, Dobrushin's next natural move was to state the coding theorems for these situations. For channel coding, Dobrushin proposed the following general principle: the coding theorem remains true if channel capacity is taken as $\sup \inf I_n$ where the infimum is over all distributions in G_n and the supremum is over all admissible distributions of channel input sequences, and he formulated sufficient conditions for this principle to be effective. For source coding, it was shown that the coding theorem holds with the rate-distortion function (RDF) $\sup R_f$, where R_f is the RDF for a given $f \in F_n$, and the supremum is over f in F_n.

Dobrushin made fundamental contributions to the study of entropy and information. He proposed a method for statistical estimation of entropy by observations. He obtained the conditions under which $I_n \to I$ as $n \to \infty$ if $(X_n, Y_n) \to (X, Y)$ and I is the mutual information of X and Y. It was also shown how it is simple for the Gibbs field to find the difference between entropy and RDF for a small Hamming distortion.

Dobrushin was also interested in the analysis of capacities for some specific channels of practical interest as well as in the analysis of the RDF for some specific sources. He developed a method for a numerical evaluation of the capacity of a channel with synchronization errors. He gave a simple deviation of a result of J. Wolfowitz that the capacity of a channel with memory is always greater than the capacity of the corresponding channel without memory. Dobrushin made important contributions in the computation of capacity of multipath channels with fading. He also considered the case where there are three sources of noise in the information transmission system – namely, before the encoder, in the channel, and after the decoder. The paper describing such a system was reprinted in "Key Papers in the Development of Information Theory" (ed. D. Slepian, IEEE Press, 1974).

Dobrushin contributed to the analysis of complexity of optimum coding. He discovered the existence of an asymptotic $(n \to \infty)$ scheme with no more than $c_1 n \log n$ functional elements and with depth $c_2 \log n$ or less, which is a linear encoder for a (n, R, nd)-code where n is the code length, R is the code rate, and nd is the minimum distance in the code. Here, c_1 and c_2 are some constants and d is less than the Varshamov-Gilbert bound, d_{VG}. He also showed that, asymptotically, a linear encoder for a (n, R, nd)-code can be constructed with only $c_3 n$ summators where c_3 is a constant depending on $d < d_{VG}$.

Dobrushin published a number of brilliant surveys on information theory which have become internationally known.

Since 1962 Dobrushin started to work on the problems of statistical physics which was to become his principal scientific interest for decades. In the autumn of 1962 Dobrushin and R.A. Minlos started a seminar at the mechanico-mathematical department of the Moscow University where its members could familiarize themselves with the basic concepts and formulations of statistical physics and thermodynamics. After three or four years of research the first important mathematical results of the participants were published. In 1965 Dobrushin obtained the first rigorous proof of existence of the first order phase transition in the Ising ferromagnetic model. Together with R.Griffiths' proof, it brought about a great wave of investigations resulting in the so-called "contour" method of study of low temperature phenomena, which has become a powerful tool of the contemporary statistical physics. The next step was the formulation of a very important notion of the limit Gibbs distribution for infinite physical systems. Dobrushin gave the general definition of this notion (a little later proposed also by O. Lanford and D. Ruelle and known now by the abbreviation DLR).

Dobrushin did pioneering research on the dynamics of random processes for which Gibbs states are invariant measures. He introduced the basic class of such processes which he called "Markov processes with local interaction." (The same class of phenomena, independently introduced by T. Liggett, is usually referred to in the West as "Interacting Particle Systems.") This class of random processes has now become one of the principal objects of research.

Since the mid-eighties Dobrushin turned his attention to the problems of nonequilibrium statistical physics, where he obtained a number of outstanding results on the derivation of hydrodynamic equations.

His discovery of the effect of "roughening transition" deserves special mention. It was quickly accepted and highly estimated by the physicists. We have here that rare situation when a mathematician discovers phenomena that have not been previously known to specialists.

In recent years Dobrushin (together with S. Shlosman and R. Kotecky) obtained a proof of the well-known Wulff hypothesis on the shape of the droplet, for the two-dimensional Ising model. They wrote a monograph on this problem where they developed a special technique of large deviations suitable for the problem. This technique is often used now in the problems connected with the study of surface tension in various models.

Dobrushin put forward the idea of extending a number of notions and constructions of statistical mechanics to problems of a different nature, in particular, to the study of random processes arising in complex information networks. He believed that "exactly solvable models" (as the ones in statistical mechanics) are just exceptions. Therefore the bulk of attention should be given to the creation of a qualitative theory of such random processes and to the investigation of various asymptotic properties. These ideas underlie many important and interesting results obtained by Dobrushin and his disciples for complex information networks.

Dobrushin contributed very much to the formation of mathematical linguistics in our country. He published several seminal articles in this domain.

This impressive (though largely incomplete) list of principal topics and directions in Dobrushin's scientific activities can give an idea of the liveliness and broadness of his intellect and of his indefatigability and perseverance to the last days of his life.

Dobrushin won unique renown among specialists in probability theory, information theory, and mathematical physics throughout the world. He was elected an honorary member of the American Academy of Arts and Sciences (1982), a foreign member of the National Academy of Sciences of the United States (1992) and a member of the European Academy of Sciences (1994). Dobrushin served on steering and program committees and was an invited speaker at many international events in mathematics, mathematical physics, and information theory.

Dobrushin was a well-known organizer of science. From 1965 to 1993 he acted as assistant editor-in-chief of the journal *Problemy peredachi informacii* ("Problems of Information Transmission"). At various times he was a member of the editorial boards of many other scholarly journals, among them *Communications in Mathematical Physics*, *Journal of Statistical Physics*, *Teoriia verojatnostei i ee prilozheniia* ("Probability Theory and its Applications"), etc.

At the Institute for Information Transmission Problems, he created a fine mathematical laboratory, making a meticulous choice of collaborators. Nowadays, this Laboratory (and the whole Institute with it) has become one of Moscow's main mathematical centers. In 1965 Dobrushin (together with M.S. Pinsker) organized at IITP a seminar on information theory and coding which has been operative ever since. Dobrushin turned out to be an excellent scientific leader greatly respected by all of his collaborators. As a leader, he had a unique ability to ignore unimportant details and focus his attention only on crucial issues.

Dobrushin devoted much effort and talent to teaching. He trained many candidates and doctors of sciences (almost all of the members of his laboratory took their Doctor's degrees). Dobrushin was a fine lecturer. His lectures, be it a scholarly paper read at a seminar or a review report at a meeting of the Scientific Council, always gathered a large audience. He had a rare gift for formulating the essence of the problem with utter clarity, so that even a non-specialist could understand it.

Everyone who had the privilege of being acquainted with Dobrushin remembers his dynamism, his firm stand on social issues, his democratic convictions and his optimism. He regarded the world with eager interest and joyfulness. It never occurred to him that there was anything worthwhile which he could fail to do or to remember. This astonishing optimism coupled with profound and clear understanding of life as it is was extremely attractive to everyone in his surrounding. It remained with him to the end of his days.

Dobrushin was fond of hitch-hiking for several days at a time in the Moscow suburbs, on foot or in a canoe, and of longer, two or three week trips in the taiga or in the mountains of Middle Asia. He traveled very much in the Soviet Union and visited all of the interesting places, from the Baltic states to the Far East.

In recent years Dobrushin traveled all over the world – from China to America. He loved to travel, not only for the sake of science but just for the thrill of it. But no matter how far he went, Russia – and he said so many times – remained the greatest attraction for him. He was always glad to be back home.

Dobrushin had five daughters whom he loved dearly. His youngest daughter Anna is now six years old.

Dobrushin's death has caused a painful reverberation in our hearts. All the people who knew him closely will always cherish the brightest recollection of him in their minds.

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