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NEWS AND NOTICES

SEVENTY YEARS OF MIROSLAV KATĚTOV

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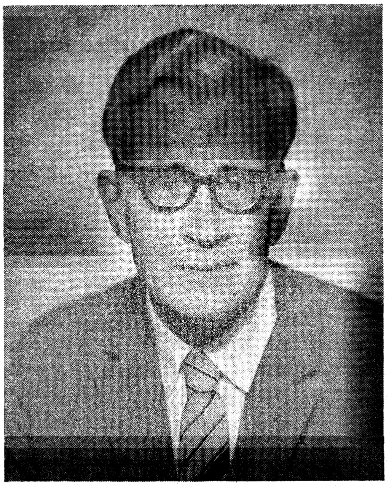
Academician Miroslav Katětov, one of the most prominent personalities of Czechoslovak mathematics, reaches seventy years of age in March. He is a distinguished specialist in topology and functional analysis and an expert in a number of other mathematical disciplines. Recently he has devoted much effort to research in non-traditional applications of mathematics in psychology, biology and medical sciences. To the wide public he is known as an outstanding Czechoslovak chess-player (Master 1938, Master FIDE 1950).



It would be hopeless to try to give complete characteristics of a personality so outstanding in all respects. Therefore I consciously restrict myself to the most fundamental data. When selecting the material I tried to concentrate on such facts which, by my experience, are not generally known, even if it meant to omit a number of important results. Particularly brief is my account of a comprehensive series of papers on etropy of spaces equipped with a probability μ (in fact, with a bounded measure) and a semimetric measurable with respect to the completion of $\mu \times \mu$. This series is to be continued by further significant papers.

M. Katětov was born on March 17, 1918 in Belinskiĭ (USSR). After completing the high school in Prague he studied at the Faculty of Science of Charles University. His decision to study mathematics was immediate. During his studies (1935–1939) he shifted to insurance mathematics, which was then the only "non-pedagogical" specialization in mathematics. Nevertheless, during his university years he got acquainted with general topology by an independent study of the world literature on the subject. His first paper [1], submitted as his dissertation, is still being cited. The dissertation was approved in 1939 by Professors V. Jarník and M. Kössler, but the graduation had to be postponed until after the World War II due to the forced closing of Czech universities by the Nazis.

During the World War II Katětov took a job in the Institute for Human Labour (which stemmed from the Psychotechnical Institute concerned with various aspects of ergonomics). His primary task was to participate in standardization of psychological tests and in the analysis of psychological and other data from the mathematical and statistical point of view. To a great extent he used the factor analysis, which was then a new method. The title of his paper "Logical fundaments of structural analysis of mental tests", which remained unpublished (but available in its galley proofs), exhibits a fresh approach to the problems. In the Institute, M. Katětov got intimately familiar with the applications of mathematical methods in psychology, thus becoming one of our first experts in the field. He has resumed research in this domain in the seventies.

During the war, Katětov attended meetings of mathematicians which took place at first in the flat of Professor V. Jarník. Here he lectured on Banach's monograph *Théorie des opérations linéaires*. He was above all interested in the notion of duality, and the papers [2] and [3] made him one of the founders of the theory of duality of locally convex spaces.

Since June 1945, Katětov was a member of the staff of the Faculty of Science and later of the newly founded Faculty of Mathematics and Physics, Charles University, till the end of 1961. Then he joined the Mathematical Institute of the Czechoslovak Academy of Sciences where he worked as a Chief Research Worker till 1983. Since then till now, he has been doing research and teaching at Charles University again.

Katětov was appointed Associated Professor in 1950 and Full Professor in 1953. When the Czechoslovak Academy of Sciences was founded in 1952, he was elected its corresponding member, and in 1962 its ordinary member – Academician. In 1950–52 he was Vice-Dean of the Faculty of Science, 1952–53 the first Dean of the Faculty of Mathematics and Physics, and 1953–57 Rector of Charles University. He also held the office of Director of the Mathematical Institute of Charles University in 1960–70. In the Mathematical Institute of the Academy he was for a number of years Head of the Department of Topology and Functional Analysis. In 1962–64, after the foundation of the Scientific Board for Mathematics of the Academy he was its chairman, in 1965–69 member of the Presidium of the Academy, to mention only the most important offices.

The number of Katětov's scientific results that initiated extensive and deep research has been extraordinarily high. The forthcoming nine paragraphs mention some of the domains of research which stemmed from Katětov's papers.

In his first paper [1] Katětov constructed the maximal H-closed extension of a Hausdorff space X, now called Katětov's extension $\varkappa X$, and ingeniously proved Stone's result (M. H. Stone: Applications of the theory of Boolean rings to general topology, Trans. Amer. Math. Soc. *41* (1937), 375–481) that a Hausdorff space is compact iff each of its closed subspaces is H-closed (the solution of a problem proposed by P. S. Uryson and P. S. Alexandrov). Let us recall that a Hausdorff space is said to be H-closed if it is closed in every Hausdorff space in which it is embedded. The maximality of $\varkappa X$ means that every continuous mapping of X onto a dense subset of a Hausdorff space Y can be extended to a continuous mapping of a set $Z \subset \varkappa X$ onto Y. In [7] Katětov characterized such X for which $\varkappa X$ coincides with the other standard H-closed extensions. From the group of papers naturally linked up with these results let us mention the solution of a problem of E. Čech: is there a dense in itself space whose each two dense subsets intersect? This problem was solved also by E. Hewitt (Duke Math. J. *10* (1943), 309–333).

The paper [3], which contains the theorem on existence of the finest topology compatible with duality, now the so called Mackey topology, has not been cited in monographs on locally convex spaces. Unfortunately, due to the unfavourable circumstances during the World War II, the proofs were published only in [10], although all the necessary tools had been prepared already in [2]. Moreover, [10] contains the proof of the more difficult part of the so called Mackey-Arens theorem: the topology of uniform convergence on w-compact convex symmetric sets of the dual is compatible with the dual; an example is given demonstrating that the convexity is essential.

M. Katětov was the first to publish [18] the solution of Birkhoff's problem concerning the existence of a rigid Boolean algebra, that is, a Boolean algebra whose only automorphism is the identity. He solved this problem elegantly with the aid of Stone's representation theorem: His rigid Boolean algebra is dual to the Čech-Stone compactification of a certain rigid countable normal space whose every point is the limit of a nontrivial sequence.

Katětov's five papers on the dimension theory from the fifties substantially affected the development of the discipline. The paper [12] gives a characterization of the covering (i.e., Lebesgue's) dimension dim of a compact space X in terms of the Banach algebra $C(X)$ of all continuous functions on X. The beauty of this characterization is apparent even in the case of metric compact spaces: $\dim X \leqq n$ iff there exist n continuous functions $f_1, \ldots, f_n$ such that the smallest algebra $\mathscr{A}$ containing all f_i and every $f \in C(X)$ which is a root of a polynomial with coefficients from $\mathscr{A}$ is dense in $C(X)$. A detailed account is given in Chap. 16 of L. Gillman, M. Jerison: Rings of continuous functions, D. van Nostrand Comp., Inc., Princeton, New Jersey, 1960. In [20], the first step was made to the generalization of the elegant dimension theory in separable metric spaces to all metric spaces: M. Katětov proved that dim X is equal to the large inductive dimension Ind X introduced by Čech. This result was obtained independently by K. Morita (Math. Ann. *128* (1954), 350–362). Katětov's proof makes use of a new important notion, the so called uniformly 0-dimensional mapping. Finally, in [23] the author establishes the inequality $\mu X \leqq \dim X \leqq 2\mu X$, which cannot be improved; here μX stands for the metric dimension (a uniform invariant). Katětov resumed his research in the dimension theory in [58] where he analyzed – from the up-to-date view-point – the approach of B. Bolzano to the concept of dimension.

For his paper [20], Katětov was granted the Klement Gottwald State Prize in 1953, see E. Čech: Miroslav Katětov – Laureate of the State Prize, Časopis pěst. mat. *72* (1953), 277–281 (Czech).

Soon after the World War II, Katětov was one of the few experts in the problems of paracompactness, normality, uniform and proximity spaces. His examples and methods from this field are still used. Let us quote several results and two problems. It has been proved in [17] that for each two suitably semicontinuous functions $f \leqq g$ on X there is a continuous function h, $f \leqq h \leqq g$, iff X is normal; if the inequalities are changed to the strict ones, one obtains a characterization of normal countably paracompact spaces. Independently of Dowker, Katětov introduced countably paracompact spaces and posed the problem whether every normal space is countably paracompact (P 108, 31. 6. 1960, New Scottish Book); and at the same time, what are the necessary and sufficient conditions on a Banach space for the weak topology to be paracompact (P 110). Let us mention that while the first problem was solved by M. E. Rudin (Fund. Math. *78* (1971/72), 179–186), the other remains open. A paracompact space is complete in the uniformity generated by continuous functions (that is, it is realcompact) iff the cardinality of any closed discrete subset is nonmeasurable [19], and similarly for the existence of the support of the measure. The result was generalized by T. Shirota (Osaka Math. J. *4* (1952), 23–40) to spaces generated by complete uniformity. A similar generalization of the result on the existence of the support of the measure appeared much later.

Let us mention two of the results from the theory of uniform spaces. A closed bounded interval is injective in the category of uniform spaces, that is, every bounded uniformly continuous function on a subspace of a uniform space is a restriction of a uniformly continuous function on the whole space [17]. The affirmative answer to the problem whether there exists a proximity such that it is not the finest one among the uniformities which generate it, was given in 1957 (On two results in general topology, Časopis pěst. mat. *82* (1957), 367 (Czech)) and published in extenso in [24]. Another solution was given by C. H. Dowker (in: Proc. 1st Prague Topological Symposium, 1961, 139–141, Academia, Prague 1962).

In [25], Katětov pointed out the importance of the minimal cardinality of the cofinal subset of functions from ω into ω with pointwise partial ordering. This cardinal number, which is now denoted by d and whose value depends on the set theory, is of crucial importance for the infinite combinatorics and has appeared in numerous surprising contexts (see e.g. E. K. v. Douwen: The integers and topology, in: Handbook of set-theoretic topology, ed. by K. Kunen and J. E. Vaughan, North-Holland (1984), 111–167).

Further, let us mention two of the ideas from Katětov's lecture [31] at the International Congress of Mathematicians 1962 at Stockholm. Aiming at the possibly most general definition of a "continuous structure", Katětov presented explicitly the following way of forming a new structure from a given one by means of a covariant functor Φ of the category of sets into itself: the new structure is the set X equipped with the old structure on ΦX; a mapping of new structured sets $f\colon \mathscr{X} \to \mathscr{Y}$ is continuous iff $\Phi(f)$ is a continuous mapping of ΦX into ΦY equipped with the old structures. This idea led to an intensive development of the categorial structure theory. As an example, Katětov himself investigated a free real module ΛX over a set X equipped with a compatible locally convex topology [28], [34]. Another example will be mentioned in the next paragraph. The second idea was the emphasis on the projective and the inductive generation of continuous structures. This led to the introduction of the so called amnestic functor and the S-functor, which is now used under the name of a topological functor.

In [33], [37] and [49] Katětov investigated the so called merotopic spaces, which later have been (and still are) intensively studied under the name of "nearness spaces". Their structure is formed by families of "small" sets. This type of a structure was used already in Morita's paper in an equivalent way as a set equipped with a system of coverings, which is a filter with respect to the relation of refinement. Let us notice that the notion had been already used by E. Čech (Fund. Math. 19 (1932), 149–183) who needed finite coverings only. It was Čech's important theorem which served as a motivation for Katětov's research: for a special class of merotopic spaces, the so called filtered merotopic spaces, the space of continuous mappings $\mathscr{X}^{\mathscr{Y}}$ can be equipped in a natural way with a merotopy such that $\mathscr{X}^{\mathscr{Y} \times \mathscr{Z}}$ is isomorphic with $((\mathscr{X})^{\mathscr{Y}})^{\mathscr{Z}}$. More precisely, the category of filtered merotopic spaces is Cartesian closed. The paper [37] develops the theory of localized filtered merotopic spaces.

In [38] the fundamental properties of the so called Rudin-Keisler ordering in ultrafilters were established. (The name was introduced later by Comfort and Negrepontis in their monograph *The Theory of Ultrafilters.*) The construction of idempotent filters in [52] is of great importance.

We have mentioned already in the introduction that M. Katětov gave up chess[1])

[1]) *D. Bronštejn - M. Katětov,* 1946. 1. e4 e6 2. d4 d5 3. Nc3 Bb4 4. e5 Ne7 5. Nf3 c5 6. a3 Bc3: 7. bc3: Qa5 8. Bd2 c4 9. h4 Nbc6 10. h5 h6 11. g4 Bd7 12. Nh4 0-0-0 13. Bg2 f6 14. f4 fe5: 15. fe5: Rdf8 16. Qe2 Nd8 17. a4 Be8 18. Bf3 Nf7 19. 0-0 Ng5 20. Bg2 Rf1: 21. Qf1: Nc6 22. Qf2 Nb8 23. Rf1 Nd7 24. Bg5: hg5: 25. Nf3 Qc3: 26. Ng5: Rf8 27. Bf3 Bf7 28. Kg2 Bg8 29. Rh1 Nb8 30. h6 gh6: 31. Rh6: Nc6 32. Rf6 Re8 33. Bd5: ed5: 34. Rf8 Rd8 35. Qf5 Kc7 36. Rg8: Rg8: 37. Qf7 Ne7 38. Qe7: Kb8 39. Kf1 Qd4: 40. Qd6 Ka8 41. Ne6 Qd1 42. Kf2 Qc2: 43. Kg3 Qd3 44. Kf2 Qd2 45. Kf3 Qc3 46. Kf4 Qc1 47. Kf3 Qf1 48. Ke3 Qg1 49. Kd2 c3 50. Kd3 Qg3 51. Kc2 Qf2 white resign.

soon after the World War II in order to be able to devote himself fully to mathematics and the organization of Czechoslovak science. Another conspicuous shift in his work came at the beginning of the seventies. Academician Katětov starts to work systematically in the applications of mathematics in psychology, biology and medicine. A seminar was founded working in this field.[2]) By means of this seminar, numerous public and colloquial lectures, and expert reports, Katětov aroused the interest of mathematicians as well as specialists in the corresponding non-mathematical disciplines.

In 1976, on the initiative of Professor P. Jedlička, M.D., and in cooperation with him, Katětov started to study the very demanding problems of the application of mathematical methods to the research of sclerosis multiplex. The aim was to create a mathematical model which would describe the complex and very variable course of the disease and in the long run give prospects of separating the effects of the medical treatment and, if possible, also of predicting the course of the disease at individual patients. Let us point out that the aetiology of sclerosis multiplex is not quite clear (though the overwhelmingly dominating hypothesis is that of virus origin), that animals do not suffer of this disease, and that the estimation of a patient's state may be affected by subjective factors. Certain features of the course of the disease led M. Katětov to a model based on the fundamental results of Thom's theory of catastrophes. Step by step a group of specialists was formed in the Mathematical Institute of the Academy and at the Faculty of Mathematics and Physics of Charles University, working on the model, see [54], [55], [57]. At present, the model covers all typical courses of the disease. Lately, a model based on the probabilistic approach has been created, and further progress may be expected to result from a synthesis of the two conceptions.

From the mathematical point of view the most important work has been done in a series of papers devoted to the notion of entropy. Recall that the mathematical notion of entropy was introduced in 1948 by C. Shannon in connection with the problems of communication. Shannon's entropy of a finite probability space is $-\sum p_i \log p_i$, where p_i are the probabilities of the elementary events. In 1956, A. Kolmogorov studied the entropy of totally bounded (= precompact) spaces P, defined as the function $\varepsilon \mapsto \log N(\varepsilon)$, where $N(\varepsilon)$ is the minimum number of sets of diameters $\leqq \varepsilon$ which cover P. Katětov posed the question whether these two notions, formally utterly disparate but whose underlying ideas are closely related, can be obtained as special cases or modifications of a single concept. A more particular question, close to the above but not identical, is the following one: is it possible to introduce, on the class of all metric probability spaces, a Shannon functional, that is, a functional which on finite probability spaces with a unit metric coincides with Shannon's entropy and possesses reasonable properties elsewhere (for instance,

[2]) See *Z. Frolík, A. Pultr:* Mathematical methods in psychology and realted fields, Aplikace Mat. *28* (1983), 77 (Czech).

a certain kind of continuity is required, as well as positive values for nontrivial spaces)? In [59], [60] an affirmative solution to a more demanding problem is given: it is shown that there exist many Shannon functionals, and some related problems are also solved. In [61] it is proved that the epsilon-entropy, studied by E. C. Posner, E. K. Rodemich, H. Rumsey Jr. (Ann Math. Statist. *38* (1967), 1000 – 1020), basically coincides with a certain modification of one of the Shannon functionals. The results of [61] together with Renyi's concept of (upper, lower and exact) dimensions of a vector stochastic variable led in [62], [65] to the introduction of various kinds of dimensions of metric spaces equipped with a finite measure. Further results, not yet published, suggest how to use the dimension to obtain the concept of the differential entropy from the notion of Shannon functional.

In the conclusion of this incomplete account of Katětov's scientific work we use the opportunity to thank him for the effort and care with which he devoted himself to the progress of Czechoslovak mathematics, and to wish him firm health, happiness and further successes in his scientific work.

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