# LIFE AND WORK OF NICU BOBOC

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*To Nicu Boboc on the ocassion of his jubilee on behalf of his Czech friends*

The text is based on the talk delivered during the Conference on Potential Theory held in Bucharest, September 23–26, 2003. Later, the extended text appeared in [A6] and the following text is a revised and extended version of it.

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Nicu Boboc (*1933) was born at Oprişeneşti, Brăila jurisdiction, Romania, which is known for oil production. Since 1951 he studied at the Faculty of Mathematics and Physics at Bucharest where he started his career as assistent professor with Simion Stoilow (1873–1961) in 1955. In 1962 he received the title Doctor of Mathematics and in the next year he became associated professor of mathematics; since 1980 he was a full professor of the University of Bucharest. In the 60's he was for several years a researcher at the Institute of Mathematics of the Romanian Academy and at present he is an honorary member of the Simion Stoilow Institute of Mathematics of the Academy.

In the 80's he was for two periods the Dean of the Faculty of Mathematics and he also served as a Prorector for Science Matters of University of Bucharest. During his teaching activities he was involved in the education of about 12 000 students (!), which are now school teachers, researchers or renown professors all over the world.

Nicu Boboc contributed to complex functions theory, theory of Riemann surfaces, partial differential equations, functional analysis and mainly to potential theory (harmonic spaces, H-cones, Markov processes, Dirichlet spaces). He is the author and co-author of five monographs and five other books. His textbooks are widely used. He is also a co-founder of the theory of H-cones developed to the large extent by Romanian potentialists.

It is rather difficult to arrange Boboc's works into disjoint groups. They are, at least formally, from different fields of mathematics but with some ex-

ceptions they have a common denominator: potential theory. To start I will describe certain singularities.

Three articles [45, 73] and [110] have general character and concern Romanian mathematics. I would like to say a few words about the first one which describes history of potential theory in Romania. In that article F. Vasilescu and M. Nicolescu are described as "fathers" of Romanian potentialists: while the first one contributed in the pre-war years to the study of the Dirichlet problem and to the continuity principle (nowadays usually attributed to G.C. Evans and F. Vasilesco), the second one studied polyharmonic functions. I mention it just to stress where one can trace the roots of what in the present time is known as "Romanian school of Potential Theory". The article also describes the situation shortly after the World War II and the influence of S. Stoilow, M. Nicolescu, N. Teodorescu, Gr. Moisil and lists their dominant areas of interests: theory of Riemann surfaces and theory of partial differential equations. This naturally, had an impact on subjects of Boboc's first works.

Seven of his works, [6–8, 10, 11, 13, 14], deal with the theory of Riemann surfaces. These articles are not devoted just to a single type of problems. Thus, for instance, one presents a characteristic of a class of metrisable surfaces, another generalizes the Lindelöf theorem on asymptotic and angular limits and in a work with Gh. Mocanu a (harmonic) metric is introduced on a Riemann hyperbolic surface. Let us mention one of the results: In [8] Boboc generalizes a theorem of R. Nevanlinna on harmonic vector field on a riemannian variety for the non-compact case.

From now on, we shall list only those of Boboc's co-authors who participated on articles and books *explicitly* described below. All co-authors can be found with the help of the attached list of publications. To compile it, the electronic form of journals *Mathematical Reviews* and *Zentralblatt für Mathematik* were used. The list is arranged chronologically and seems to be (up to recent time) complete. From now the chronology is not respected. We will turn to the main fields of Boboc's interests.

In the fifties of the last century abstract theories covering some parts of potential theory appeared. Axiomatics of M. Brelot covered the "elliptic case" only while that of J.L. Doob and H. Bauer enriched the area of investigations with the "parabolic case". In the Bauer's axiomatics there is a problem with a sufficiently simple proof of the *base axiom of regular sets*. It seems that at any case it requires some non-trivial facts outside from potential theory. Another solution was offered by Romanian potentialists and culminated by publishing of the monograph [A3] of C. Constantinescu and A. Cornea. Boboc's works significantly helped to realize this project: a glance on references in the book shows that 18 of his works (with co-authors) is listed. Some of them formed

first steps on the way to this book. I give only a few examples: [15, 16, 19, 20, 23, 24, 26, 28, 30, 31].

In the seventies the theory of *harmonic spaces* was considered to be a bridge between analytic and probabilistic potential theory. At the same time (this opinion may be found in [45]) certain splitting could be traced: three branches (roots of which are much older) of the theory were already relatively independent. Thus, except for an "analytic approach" represented by the theory of harmonic spaces also, *study of processes* and *study of convex cones*, were more and more important.

After studies of properties of abstract kernels generating potentials having special properties and together with Choquet's theory the importance of investigations of various cones increased. Let us take now a look on Boboc's works formed by articles on various cones of continuous or lower-semicontinuous functions. To this group we can include works [21, 25, 29, 34, 36, 38, 43, 46–48] but also some others as well.

The book [B4] (with Gh. Bucur) contains a summary of results obtained to the time. From its review by G.J.O. Jameson in Mathematical Reviews I quote: "A translation into a more widely known language will be eagerly awaited. In the meantime, workers in this field would do well to make use of the AMS instant Romanian course; it really does not take long to equip oneself to read mathematics in Romanian."

The above mentioned book of C. Constantinescu and A. Cornea contributed to the increase of interest in axiomatic potential theory. Their axiomatics has a *local* character. Other axiomatic approaches followed and they even strengthened the role of special cones. In 1981 another book [B6] written by Boboc (with Bucur and Cornea) was published; it brought the theory of H-cones. Its birth is connected with two short notes [37] and [38] (with Cornea) published in 1970. Remark, that H-cone is an ordered convex cone, that is a subcone of positive elements of an ordered vector space with a few natural properties patterned after situations in potential theory.

The list of Boboc's works related to this theory is quite long. It includes at least [39, 40, 52, 56–60, 63, 64, 66–72, 74, 77, 79–86, 89–92, 95, 98, 99] and [117]. This sequence contains only small gaps. One can see that Boboc's work was for a relatively long time very much connected with the development of this problematics. Other two remarks: It is a voluminous *theory*, not just a small set of results. This theory covers also *non-local* cases and provides an approach to duality. Other non-local axiomatic potential theories exist, for instance, of Bliedtner and Hansen [A2] (balayage spaces).

Before turning to the last rather big group of Boboc's publications we attempt to describe articles which correspond to other areas of mathematics

laying a bit further from potential theory. Another field of activity of Boboc is represented by works on partial differential equations. His interest in the field started relatively early. At least seven works, [1, 3, 5, 22, 27, 42, 49], and in a way also [127, 129, 134], can be listed in this group. In those works various problems were studied, *e.g.*, apriori estimates for solutions of the Dirichlet problem [49] (with G. Albinus and P. Mustaţă) or the existence of Green function for equations of elliptic type on differentiable manifolds [5] (with N. Radu). In [27] (written with P. Mustaţă) a necessary condition for domains of uniqueness for second order uniformly elliptic operator is given; the corresponding problem was posed by C. Miranda. Later in [42] the authors returned to the question in much more general framework of harmonic spaces, but even before its appearance Boboc and Mustaţă published [B2].

One of the first articles [2] contains an example of everywhere discontinuous Darboux function, another [75] contains a necessary and sufficient condition for analyticity of a real function. Similar question in the context of real Banach spaces is studied in [109]. Article [12] deals with Luzin's and Menchov's properties. Article [4] (with S. Marcus) is devoted to the determination of functions by their values on a certain set.

Measure theory is a natural ingredient of majority of Boboc's articles listed above. Now let us mention a "pure" measure theoretic result from [61] (with Gh. Bucur): A positive countably additive measure $\mu$ on a ring of sets $\mathbb{R}$ is said to be *semifinite* if $\mu(A)$ is a supremum $\mu(B)$ for all $B \subset A$ such that $\mu(B)$ is finite for every $A \in \mathbb{R}$. A semifinite measure $\mu$ is said to be Archimedean if there exists no non-trivial semifinite measure $\gamma$ such that $n\gamma \leq \mu$ for all $n \in \mathbb{N}$. It is shown that this notion is strictly in-between the notions of $\sigma$-finite and semifinite measures. The Archimedean measures (which can be used in some Fubini-type theorems instead of $\sigma$-finite measures) are then studied and some open problems on these measures are formulated.

There are subjects which occur in several works, for instance, the axiomatic study of *polyharmonic functions* ([44, 50] and [53]) from which the first two articles were written with Mustaţă. Except polyharmonic functions of Nicolescu they provide an abstract framework for Bernstein's completely monotone functions or completely concave functions of Widder. Special aplications of the theory of H-cones are presented in [87, 93, 103, 104, 106] and [120]. Three of them, [93, 106] and [120] (written with Bucur) when applied to natural numbers with the order relation based on divisibility, lead to an interesting relation among seemingly totally independent areas of mathematics: potential theory and number theory.

There are results which seem to be somewhat singular in a sense that they have no special analogue in other works. Thus, in [54] a theorem on extend-

ability of harmonic mappings is proved. It is a result generalizing theorem on removable singularities for holomorphic functions. Paper [29] (with Cornea) is devoted to a generalization of the theorem on behavior of solutions of the Dirichlet problem at an irregular point. Two papers [33] and [35] deal with domination principle and contain a generalization of results from a well-known book of P.-A. Meyer [A6].

In the article [41] another extendability problem is solved: Let $H$ be a linear subspace of $C(X)$ containing constants and separating points of a compact Hausdorff space $X$. If $F$ is a closed subset of $X$ containing the Choquet boundary of $X$ with respect to $H$, and $H_1$ is a linear subspace of the $H$-affine continuous functions on $X$ then necessary and sufficient conditions are given for a continuous $H$-affine function on $F$ to be extendable to an $H$-affine function on $X$ and in $H_1$.

As mentioned above there is another large part of potential theory dealing with its probabilistic aspects and interpretations. In this area we can find also deep traces of Boboc's activity. I include to the corresponding group of works also these which bring *analytic approach to probabilistic results*. This group contains works [76, 78, 94, 96–98, 100, 101, 105, 107, 111–113, 116, 121] and [133]. In the work [97] (with Beznea) the authors give some results previously obtained in [B6] under more general situation.

About twenty years ago Boboc and Beznea started a study of kernels of a special type. They were able to build up for them very nice and deep results. I quote here a rather qualified opinion of P.J. Fitzsimmons and R.K. Getoor from [A4].

"In a recent series of papers L. Beznea and N. Boboc have singled out an important class of kernels for which they have developed a rich potential theory. These kernels (called regular strongly supermedian kernels) are those that map positive Borel functions to strongly supermedian functions of a strong Markov process $X$ and that satisfy a form of the domination principle. Using entirely potential theoretic arguments, Beznea and Boboc were able to develop a theory of characteristic (Revuz) measures, uniqueness theorems, etc., (...) that parallels a body of results on homogeneous random measures due to J. Azéma, E.B. Dynkin and others. In fact, the theory developed by Beznea and Boboc goes far beyond that previously developed for homogeneous random measures." In [A4] its authors studied the problems of the same sort but they used purely probabilistic technique.

Boboc together with Beznea continued the study of regular strongly supermedian kernels. Their results are included in the monograph [B10] and furthemore developed in several articles like [123, 124, 130–132]. They also returned to the roots of the theory of regular strongly supermedian kernels

and (in collaboration with M. Röckner) wrote a series of articles dealing with Dirichlet forms and $L^p$-resolvents in [125–127] and [129].

In the book [A5] Kigami introduced a notion of so-called resistent form. Boboc studied (together with Gh. Bucur) an analogous non-symmetric notion and developed for the case a nice part of potential theory in [130, 131] and [135].

Still, I omitted some articles bringing important, interesting and deep results. Nevertheless, I hope that all important ideas on mathematics in the works of Nicu Boboc were presented. Mathematics has been for him a lifetime love and he, in the circle of his collaborators, friends and pupils, is her ageless lover and humble servant as well.

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**Articles**

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