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STOJAN M. BOGDANOVIĆ – SCIENTIST, TEACHER, AND POET *

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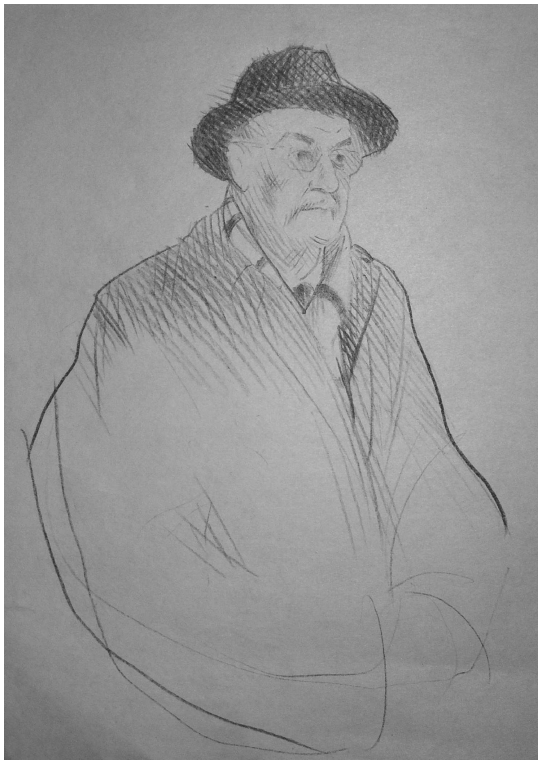

Professor Stojan M. Bogdanović
(Drawing by Dragoslav Živković)

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This year, students and friends of Stojan Bogdanović celebrated his 65 birthday. Stojan was born on June 21, 1944, in Veliko Bonjince, Babušnica, Serbia. His education started with primary schooling in Knjaževac, where he also finished gymnasium. Stojan graduated in Mathematics at the University of Belgrade in 1968, and specialized in Axiomatic set theory at the University of Paris VII, in 1974/75. He defended his Ph.D. thesis at the University of Novi Sad in 1980, under supervision of Svetozar Milić, who also supervised majority of the most known algebraists in Serbia.

His professional life Stojan began as a gymnasium teacher in Pančevo (1968-77), and after that he worked at the Faculty of Sciences and Mathematics, University of Novi Sad, where he was promoted to assistant professorship in 1981. Moving to the Faculty of Economics, University of Niš, in 1986-87, he became a full professor there in 1989. Now, he is also a teacher at doctoral studies at the Faculty of Science and Mathematics and Teacher-Training Faculty, University of Niš.

The most of Stojan's scientific career has been devoted to semigroups. He began research in this area by considering problems of Von Neumann's regularity in semigroups and rings. This subject in his research extends to the present time, and one of the most valuable results was obtained in [136], where it was shown that the regularity of semigroups can be defined by linear equations in exactly fourteen ways. This generalizes the well-known Croisot theory presented in the Clifford and Preston's book [The Algebraic Theory of Semigroups, Vol. 1, Amer. Math. Soc., 1961]. In 1982 Stojan started a systematic study of the *π-regularity*, a natural generalization of regularity, where an element may not be regular, but some its power is regular (cf. [30]). The class of π-regular semigroups is a very important and a quite wide class of semigroups. Among other things, it includes all finite semigroups which play a very important role in practical applications of the semigroup theory. Results of his study of π-regular semigroups are one of his greatest scientific contributions overall.

Stojan's specialty is the general structure theory of semigroups, where he published a lot of high-quality articles which have promoted him to one of the leading experts in the world in this field. We single out two basic problems which engrossed him. The first one is the *decomposition problem* which can be stated as: find a way to break a semigroup in parts, with as simple as possible structure, then examine these parts in detail, as well as relationships between the parts within the whole semigroup. The second problem is the *composition problem* worded as follows: find a way to build a semigroup with the desired properties from the given parts.

Stojan Bogdanović not only made an immense contribution to the further development of the known methods for decomposition and composition of semigroups, but he has also introduced many new effective decomposition and composition methods which have been applied to certain classes of semigroups. Undoubtedly, the most important among them are methods for the decomposition of a semigroup into a semilattice of completely archimedean semigroups. The first fundamental results concerning such decompositions were announced by L. N. Shevrin at the conference in 1977, but he has published detailed proofs after 17 years [Mat.

Sbornik 185 (8) (1994) 129–160; 185 (9) (1994) 153–176]. Other authors have tried to study these decompositions building their own methodology, e.g., J. L. Galbiati and M. L. Veronesi [Rend. Ist. Lomb. Cl. Sc. (A) 116 (1982) 180–189; Riv. Mat. Univ. Parma (4) 10 (1984) 319-329], and others. Stojan began with research in this area sometime about 1985 (cf. [38]). In a series of articles that were published later, he and his coworkers managed to create their own methodology, which led not only to the same results that were announced by Shevrin, but also to their significant improvement. A complete theory of decompositions of a semigroup into a semilattice of completely archimedean semigroups has been exposed for the first time in the book [5].

Central place in Stojan's study of decompositions of semigroups is held by the general problems of the existence of the greatest decomposition of a given type, the decomposition with the finest components, and characterization and construction of the greatest decomposition, if it exists. Another important question is whether the given type of decomposition is *atomic*, i.e., whether the components of the greatest decomposition of this type are indecomposable by means of decompositions of the same type. Perhaps his greatest achievement is the theorem published in [83] which states that *every semigroup with zero can be decomposed into an orthogonal sum of orthogonally indecomposable semigroups*. The referee of this article said that "the result sounds classically and it is amazing that no one has proved it for more than forty years, when orthogonal decompositions were introduced". In the semigroup theory only five types of atomic decompositions are known so far. The atomicity of *semilattice decompositions* was proved by Tamura [Osaka Math. J. 8 (1956) 243–261], of *ordinal decompositions* by Lyapin [Semigroups, Fizmatgiz, Moscow, 1960], of the so-called $\cup$*-decompositions* by Shevrin [Dokl. Akad. Nauk SSSR 138 (1961) 796–798], of *orthogonal decompositions* by Bogdanović and Ćirić [83], whereas the atomicity of *subdirect decompositions* follows by a more general result of universal algebra proved by Birkhoff [Bull. AMS 50 (1944) 764–768].

Stojan Bogdanović has also achieved outstanding results in the theory of the greatest semilattice decomposition of semigroups. This theory has been developed from the middle of 1950s to the middle of 1970s by T. Tamura, M. S. Putcha, and others. For a long time after that there were no new results in this area. In the middle of 1990s, Stojan and his coworkers initiated further development of this theory by introducing completely new ideas and methodology. The most important results were published in [88, 100, 119]. In the review of [88] in Mathematical Reviews, the founder of this theory Tamura wrote that "the reviewer is impressed by the fact that the greatest semilattice decomposition established 40 years ago has been much developed to date".

There is also a series of papers in which some syntactic properties of semigroup identities (special arrangement of letters) have been studied from the aspect of their influence on certain structural properties of semigroups and rings that satisfy these identities (special types of decomposition), as well as from the aspect of their validity on particular finite semigroups. Such questions have been discussed in [72, 69, 75, 89, 121], in the case of semigroups, and in [86, 111], in the case of rings.

In study of the composition methods, Stojan's attention has been most focused toward subdirect products, and in particular, toward pullback products. *Pullback products*, in semigroup theory also known as the spined products, are not only easier to construct than other subdirect products, but also preserve some properties of semigroups which other subdirect products do not necessarily preserve, for example, the complete regularity. In most cases, subdirect and pullback products have been related to other important composition methods, band and semilattice compositions determined by certain systems of homomorphisms (cf. [57, 71, 90, 91, 104]). In [65] and other papers subdirect and pullback products have been related to retractive extensions of certain types of semigroups. Band compositions determined by systems of homomorphisms have been mostly studied in cases when the components are monoids, and general constructions of bands and normal bands of monoids were given in [54, 70]. Subdirect and pullback products have been also studied from another aspect. As known, any representation of a semigroup in the form of a subdirect or pullback product is determined by a certain system of congruences on this semigroup. Effective constructions of some such systems of congruences on regular and completely regular semigroups have been given in [146] (see also [117]), and in [110, 157] pullback products determined in that way have been applied to study of the lattices of varieties of bands and lattices of varieties of idempotent semirings.

In the second half of the 1990s, the research group led by Stojan Bogdanović and the first author of this article, redirected their research towards applications of the semigroup theory and general algebraic systems in theoretical computer science. Wide algebraic foundation was very fruitful in research in the theory of automata and formal languages, as well as in other branches of theoretical computer science. As a result, a comprehensive study of *directable automata*, and their generalizations and specializations, was carried out (cf. [109, 112, 129, 130, 132, 133]). It turned out that the considered classes of automata have very interesting algebraic properties, which led to establishing Eilenberg-type correspondences between unary algebras, automata, semigroups and congruences on free semigroups in [137, 142]. From the aspect of their natural interpretation as a parallel composition of automata, subdirect products of unary algebras were studied in many papers. The best results were given in [114], where all subdirectly irreducible unary algebras were described using methodology that comes both from the semigroup theory and universal algebra.

Research in the semigroup theory and the automata theory naturally led to numerous questions concerning general algebraic systems, ordered sets and lattices, and Stojan Bogdanović devoted many articles to these questions. Perhaps his most interesting result in these areas is one new equivalent of the famous Birkhoff Variety Theorem, given in terms of properties of the congruence lattices of algebras, published in [94]. In the review of [101] in Mathematical Reviews, referring both to results from [94] and [101], David Hobby stressed that "one feels that they should be part of the "folklore" of universal algebra".

In the middle of 2000s Stojan's research group again changed the main direction of research. Then the main topic of research became fuzzy automata, as a natural

generalization of ordinary deterministic and non-deterministic automata, and the foundations were laid of the algebraic theory of fuzzy automata and languages based on complete residuated lattices as the underlying structures of truth values. Study of fuzzy automata required prior research in the theory of fuzzy relations, as was done in [144, 148, 149, 156]. Applying the obtained results, the Myhill-Nerode type theory for fuzzy automata and laguages has been developed [151], and a new algorithm for determinization of fuzzy automata has been given [145].

Stojan also wrote a lot of comprehensive survey articles. The most important results concerning uniformly π-regular semigroups, i.e., semigroups decomposable into a semilattice of completely archimedean semigroups, were collected in [69], and in [111] these results were supplemented with some new results and the corresponding results concerning rings. Articles [74, 79] give an overview of the main results of the theory of greatest decomposition of semigroups, and deal with semilattice and band decompositions, decompositions of semigroups with zero, and others. Another approach to semilattice decompositions was presented in [105]. Two survey articles are devoted to automata. The article [106] discuss lattices of subautomata and direct sum decompositions of automata, and [112] deals with directable automata, their generalizations and specializations.

Stojan Bogdanović published four scientific books [3, 4, 5, 6]. The first one, the book [3], was written in English and has attracted considerable attention of authors from all over the world. It was particularly popular among Chinese authors, and it is the most cited Stojan's publication. Material from [3] was later significantly expanded and included in the book [5]. This book was written in Serbian, but it was also widely used by foreign authors, especially by authors with good knowledge of some of the Slavic languages. In the review of this book [Semigroup Forum 55 (1998) 297–299] Boris M. Schein noted that it is the eleventh monograph in the general algebraic theory of semigroups, written in the fifth language (the previous ten were written in Russian, English, Japanese, and Romanian). If the book was written in English, it would certainly have much greater impact on science at the international level, but writing the book in Serbian proved to be very useful for the building of Serbian terminology in this area, where previously such terminology did not exist.

Stojan's scientific contribution is reflected not only in the above mentioned research results, but also in his teaching and supervising work. He is equally brilliant as a scientist and as a teacher. Thanks mostly to his inspiring lectures in basic abstract algebra the first author decided to research in algebra, and already in the first year of study of mathematics, he started joint research with Stojan. Stojan is even more brilliant as a supervisor. We have not met anyone who has so much to offer its students, and who gives so unselfishly. Working with him is so easy. If you want him to unselfishly introduce you to the world of science, the only thing you have to promise him is that you will tomorrow be so selfless to your students. We also remember his words: "If you want to work with someone, then you must be a friend with him, you must fully understand him, and you must respect his problems and help him, both in professional and private life". And then, it is not so hard to publish more than one hundred joint articles with him, as the first author did.

Key role in introducing young people in scientific research played a scientific seminar, the idea that Stojan brought from his studies in Paris. When in 1982 he began teaching algebra to students of mathematics at the University of Niš, with Vladimir Rakočević he launched the *Seminar for semigroup theory and functional equations*. Over time, two largest and the most active mathematical seminars and scientific groups, not only at the University of Niš, but perhaps in the whole Serbia, resulted from this seminar, one in functional analysis, and the other in algebra, and later in theoretical computer science. Scientific seminars headed by Stojan, and later by the first author of this article, led to 13 Ph.D. theses and 19 M.Sc. theses defended (the number of Ph.D. theses is constantly increasing), with 6 Ph.D. theses and 11 M.Sc. theses supervised by Stojan.

Stojan is not only an outstanding scientist and an excellent teacher, but also a very successful and internationally recognized poet. He has published six books of poems. His poems have been included in several anthologies and collections of the modern Serbian poetry, as well as in several international anthologies, and they have been translated into English, French, Romanian, Italian and Greek. He is a member of the Association of Writers of Serbia. Apart from scientific and professional articles and books of poetry, Stojan has published more than 50 articles and essays in other areas, such as philosophy, literature, fine art, economics, politics, etc.

List of publications of Stojan Bogdanović

I Theses

1. S. Bogdanović: *On a class of semigroups*. M. Sc. Thesis, University of Novi Sad, Faculty of Sciences and Mathematics, 1978 (in Serbian).
2. S. Bogdanović: *Contribution to the theory of regular semigroups*. Ph. D. Thesis, University of Novi Sad, Faculty of Sciences and Mathematics, 1980 (in Serbian).

II Scientific Books

3. S. Bogdanović: *Semigroups with a System of Subsemigroups*. Institute of Mathematics, University of Novi Sad, 1985.
4. R. R. Stanković, M. Stojić, and S. Bogdanović: *Fourier Representations of Signals*, Naučna knjiga, Beograd, 1988 (in Serbian).
5. S. Bogdanović and M. Ćirić: *Semigroups*, Prosveta, Niš, 1993 (in Serbian).
6. M. Ćirić, T. Petković, and S. Bogdanović: *Languages and Automata*, Prosveta, Niš, 2000 (in Serbian).
7. S. Bogdanović, M. Ćirić, and Ž. Perović (Eds.): *Algebra, Logic and Discrete Mathematics*. Papers from the conference held at the University of Niš, Niš, April 14 -16, 1995 - special issue of Filomat (Niš) 9:3 (1995), vi + 581 pp.

III Research Papers

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9. S. Bogdanović and S. Crvenković: *On some classes of semigroups*. Zbornik radova PMF Novi Sad 8 (1978), 69–77.
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17. S. Bogdanović: *On weakly commutative semigroups*. Matematički Vesnik 5 (18) (33) (1981), 145–148 (in Serbian).
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