Early work in Switching Theory and Logic Design of Gavrilov School in former Soviet Union

[1]Anatoly A. Shalyto, [2]Radomir S. Stanković, [3]Jaakko T. Astola, [4]Alexander V. Strukov
[1]ITMO University, St. Petersburg, Russia
[2]Dept. of Computer Science, Faculty of Electronic Engineering, Niš, Serbia
[3]Dept. of Signal Processing, Tampere University of Technology, Tampere, Finland
[4]AO "SPIK SZMA", St. Petersburg, Russia

***Abstract*—This paper is a review of early work in Switching theory and Logic design in former Soviet Union and presents certain details about organization of research activities at that time and points out important research centers and renowned scholars and areas of their main activities. In particular, we discuss the work conducted by Michael A. Gavrilov and also descendant research schools in the area.**

I. School of Gavrilov

The presentation in this paper is based on the text written by Anatoly A. Shalyto at a web page discussing the school established by Mikhail A. Gavrilov (www.computer-museum.ru/Gavrilov). This and related topics are also considered in [30], [31], [32], where an overview of former work of scholars and scientific schools in the area of logic networks and automata theory in former Soviet Union is presented. A professional biography of Gavrilov can be found in [26], [28].

The design of computing and communication devices based on discrete and digital components is an essentially important subject of research and engineering practice. Already in late fifties and early sixties, it attracted a great attention of researchers all around the world, with Soviet Union not being an exception.

According to the practice of organization of the scientific activities at that time in Soviet Union, the research work in this area was carefully planned, organized, and conducted by renowned well-respected researchers. In that respect, a school on the theory of relay devices and finite automata was organized by a member of the USSR Academy of Sciences, Mikhail Aleksandrovich Gavrilov (1903-1979), who for many years worked at the Institute of Control Sciences (Institute of Automation and Remote Control Sciences), Academy of Sciences of the USSR, Moscow, (http://www.ipu.ru/en) in the famous Profsoyuznaya street 65 building, and already at the time of the start of the school had a decisive contribution to the development of applied theory of automata.

This school that now bears the name of Gavrilov, Gavrilovsky school, can be viewed as a unique phenomenon that hardly has analogues in the contemporary world of science. It is hard to recognize a similar school in some other area of science, in any country in the world, that would have existed for more than forty years with meetings of the School held in different cities of the USSR.

From the School of M. A. Gavrilov, a number of other schools in digital system design evolved, e.g., the schools for diagnosis, for modular structures, design automation.

During this time, the school was attended by hundreds of people, so that it is hard to enumerate all of them, the same is with pointing out all important achievements and results.

Notice that the journal "Automation and Remote Control", founded and edited in the Institute of Control Sciences, ceases to be a bulwark of this research direction. The policy of this journal is to no longer accepts articles on logic synthesis, assuming that presently this area is not a scientific, but rather technological subject. Although, as the S. V. Yablonsky used to say, "If science is not speculative, it does not become obsolete".

The theory of relay devices began to develop in the world with the pioneering work of the Japanese scholar Akira Nakashima around 1935 [43], [48]. In 1938, Claude E. Shannon (1916-2001) published a similar work titled "Symbolic Analysis of Relay and Switching Circuits" [33], which had a huge impact on the development of this field of science in the world. Victor I. Shestakov (wikipedia.org/Shestakov) (1907-1987) in 1941 published a paper "Some mathematical methods of designing and simplifying bipolar circuits Class A" [34], that was prepared in the manuscript form in 1935-1938 at the Physics Department of Moscow State University of M. V. Lomonosov.

Notice that, before Shestakov in USSR, and thirty years ahead of Americans I. S. Reed and D. Muller, in Kazan, USSR, I. Zhegalkin (wikipedia.org/Zhegalkin), performed research in functional representations in Boolean rings already in early twentieths of last century (www.mathnet.ru/Zhegalkin).

A. A. Shalyto (wikipedia.org/Shalyto) witnessed that the work of Zhegalkin from 1927, although written in Russian, was known to a military expert from Pentagon engaged in NP-hard problems attending a conference on situational control in 1995 in the United States (http://is.ifmo.ru/science/) (See the file *Shalyto, A.A., Cognitive Properties of Hierarchical Representations of Complex logic Structures.pdf*) Recall that the first task for which it has been proven NP-complete, is the problem of "Satisfiability of Boolean formulas", and all

the other tasks of this class can be reduced to it. From there, it is clear what was the motivation for a renewed interest in the work of Zhegalkin.

It should noticed that long before Zhegalkin, in Kazan, research was carried out by Platon S. Poretsky, the author of the seminal works on mathematical logic presented and published already in 1884 [42]. The possibility of application of algebra of logic in the design of relay circuits have been pointed out by Charles Pierce in 1885 [25], and in Russia by Paul Ehrenfest, a physicist working at that time in St. Petersburg (1910). The list of forerunners in the design of relay circuits should include also Russian compatriots A. Kutty and M. Timbalistij (1928) [45].

After the work of V. I. Shestakov in this field, came the era of M. A. Gavrilov in the Soviet Union, which could (if there would not be the fight with cybernetics, the Iron Curtain, and other charms typical for USSR) change the area on the world level, especially since C. E. Shannon departed very soon from the work in this area.

M. A. Gavrilov began his scientific work in telemechanics working towards theory and practical applications of remote control systems, in which the relay based devices were built heuristically. He came to the conclusion that this class of devices can be synthesized using formalized methods, about which he wrote one of the first in the world books, *Theory of Relay-contact Circuits*, Moscow, Publishing House of the USSR Academy of Sciences, 1950. Recall that the first book on the subject was published in 1947 by the Austrian scientist O. Plehl under the title "Schalter und Apparatebau".

However, the work of Gavrilov was not smooth and easy. Gavrilov had to wait for the defense of his doctoral thesis on the subject until in 1946. The defense was possible just thanks to the efforts of the philosopher and mathematician Sofya Aleksandrovna Janovskaja, who was able to convince the authorities that the usage of Boolean algebra in the synthesis of logical circuits is not an idealism, and especially it is not contrary to Marxism-Leninism, etc. Thanks are due also to Aksel Ivanovich Berg for the support of the same efforts. More details about the problems that Gavrilov had regarding defending of his dissertation and also similar circumstances related to the work of some other members of his school can be found in the article by A. A. Shalyto entitled *"Far and Close"* at the virtual computer museum (http://www.computer-museum.ru/articles/galglory_ru/1042/). In the same context, see also another articles by the same author *"Works on multi-functional and customizable modules performed in USSR and Russia"* (http://www.computer-museum.ru/articles/books/1064/) and *"Work on homogeneous structures and cellular automata performed in the USSR, Russia and Ukraine"* (http://www.computer-museum.ru/articles/books/1066/).

Further, Gavrilov was elected in the Academy of Sciences relatively late, in 1963. Interestingly, an artistic book about Gavrilov and his associates was written, which is rarely happen to scientists, especially not during their lives. Yuri Weber published a book entitled "When the Answer Comes", by publishing company "Detgiz"! This book was later reprinted by the publishing house "Belles-lettres" in the series "Road to the Unknown."

It might be observed that the real beginning of this few decades long excellent work started after the book of M. A. Gavrilov was published in 1950.

We mention here just two among many associates of Gavrilov.

Gellius Nikolaevich Povarov (www.mathnet.ru/Povarov), (www.computer-museum.ru/Povarov), has published over then papers in fifties, even before defending his candidate of doctor of sciences dissertation. For some reason, Povarov did not become a doctor of sciences, but in spite of that he become a very renowned scientist with a dozen of articles in the "Reports of the Academy of Sciences". Recall how high was the level of publication at that time in the majority of former dissertations, in particular, for the candidate of the doctor of science, and especially in computer science.

P. P. Parkhomenko (http://www.mathnet.ru/Parkhomenko), received a gold medal for the machine to minimize relay circuits at the World Exhibition in Brussels in 1956.

II. Cooperation with Scholars Abroad

The situation of research in switching theory and in mathematical logic in general in USSR was deeply influenced by the political circumstances. After the October revolution, mathematical logic was viewed as a bourgeois science coming from the West and therefore its idealism was considered as inappropriate for the socialistic moral and spiritual development. Within attempts to determine and properly formulate a Marxist-Leninist view of the philosophy of mathematics and mathematical logic in particular, an important role was played by the edition of the *Mathematical Manuscripts* of Karl Marx and especially comments made on them by several Soviet scholars, including S.A.Janovskaja, V. I. Glivenko, L. P. Gokieli, E. Kolman [8]. It is commonly accepted that a major contribution to the turn over of the point of view to mathematical logic and philosophy of mathematic in general is due to the engagement and work by the above mentioned S. A. Janovskaja, a Professor of Moscow State University, who put considerable efforts to establish a proper point of view to these areas, and the vehicle to that was to explain that there is no a contradiction in fundamentals of these areas with respect to dialectic materialism. The professional and pedagogical work of Janovskaja as well as her reviews of the mathematical work in Soviet Union traced a way towards normalization of the situation in the mathematical research in USSR as it is commented by several authors of analytical overviews [1], [2], [4], [5], [9], [13], [14], [17], [47].

Due to these efforts of many scientists, and also the change of the political circumstances, it was a relaxation of ideological pressure and an increased liberty in performing research in mathematical logic and switching theory as a facet of it oriented towards concrete engineering applications. This area was accepted and supported as a topic at top institutions as it can be seen, for example, from the defense in 1938 of the

Fig. 1. Viktor Ivanovich Shestakov

PhD Thesis by Victor Ivanovich Shestakov at the Lomonosov University in Moscow [35], or the organization of the research group working in algebra of logic, specifically, the arithmetic logic at the Institute of Control Sciences in Moscow, see for example, the work of Vladimir Dmitrievich Malyugin (www.mathnet.ru/Malyugin) [18], [19], [20], [21], [22], [23], [24], or at some other institutions [3], [10], [11], [12], [29]. Main results from the PhD thesis of Shestakov were published in [36], [37], and his further achievements were reported in many publications, to point out just [38], [39], [40], [41]. More details about biography and work of Shestakov can be found in [17].

An interesting detail from that time worth mentioning is the following.

After successful organization of the First Workshop on Switching Theory in 1951, followed by the afterwards publication of the Report *Synthesis of Electronic Computing and Control Circuits* [46], Howard Aiken organized *International Symposium on the Theory of Switching* on April 2-5, 1957, the proceedings of which were published in 1959. Participation of scholars from the Eastern Europe (East Block) was planned, however, various circumstances prevented that. To preserve the program as initially composed, but also to provide information to western scientist about the work in East Europe and Soviet Union, Aiken asked his associates to learn the subject and present the work on behalf of the authors. This was at the same time a favor to the authors to have their results reported at the audience wider that the scholars in the East Block.

As we can read from the preface written by H. Aiken,

The program was planned through the efforts of the present writer, Robert Ashenhurst, Warren Semon of the Staff of the Computation Laboratory, and went through several sessions. After the final printing on March 29, 1957, messages were received from Antonin Svoboda of Czechoslovakia and Michael A. Gavrilov, Gellias N. Povarov, and Vadim N. Roginskij of the Union of Soviet Socialist Republics announcing that they would be unable to attend. Since their papers had already been received they were read by Albert L. Hopkins, Kenneth E. Iverson, Robert Ashenhurst, and Anthony G. Oettinger, respectively. Thanks are due to these members of the Staff of the Computation Laboratory for their willingness to undertake these tasks at the eleventh hour. Thanks are also due Walter Vickery, Nicholas Vitt of the Russian Research Center, and Mark Pivovonsky, Anthony Oettinger, and Peter Calingaert of the Computation Laboratory for their efforts in translating the papers of Misters Gavrilov, Povarov, and Roginskij. On April 5, a letter was received from Alexander Veits of the Union of Soviet Socialist Republics to the effect that he had mailed his paper but will be unable to attend in person. Unfortunately this contribution has apparently been lost in transmission and hence cannot be included in these proceedings.

Fig. 2. Vladimir Dmitrievich Malyugin at the bridge over the river Nišava in Niš, Serbia

The complete references of these papers by Soviet Union authors are

Gavrilov, M. A., "A survey of research in the theory of relay networks in the USSR", *Proc. Int. Symp. Theory of Switching*, Harvard University, Cambridge, Mass., Pt. 1, April 1957, 26-53.

Povarov, G. N., "A mathematical theory for the synthesis of contact networks with one input and k outputs", *Proc. Int. Symp. Theory of Switching*, Harvard University, Cambridge, Mass., Pt. 2, April 1957, 74-94.

Roginskij, V N., "A graphical method for the synthesis of multi-terminal contact networks", *Proc. Int. Symp. Theory of Switching*, Harvard University, Cambridge, Mass., Pt. 2, April

1957, 302-315.

In these papers by Gavrilov and Povarov, the reference to the review of Paul Ehrenfest [7] of the book by Louis Couturat [6] is provided. For this review, see [44].

It is important to notice the closing remarks from the review article of M. A. Gavrilov

A very important task is the automatization of the synthesis of relay networks. In the Soviet Union initial successes have been attained in this field; however, this work requires further development and broadening.

The friendly cooperation of scientists of various countries will undoubtedly permit the solution of the problems set above in a somewhat shortened period of time. The scientists of the Soviet Union are ready to make their further contribution to the development of work in the theory of relay networks.

It is interesting to mention that the Serbian mathematician Djuro Kurepa (George Kurepa in English) (www-history.mcs.st-andrews.ac.uk/Kurepa) and (wikipedia.org/Kurepa) from former state Yugoslavia participated at the Symposium and presented the paper "Sets - Logics - Machines", pages 137-146. [1] This fact expresses in a way a specific status of former Yugoslavia as a country between the two political blocks.

Recall that several important mathematical concepts were introduced by Professor Kurepa and are called by his name, for example, Kurepa tree, Kurepa topology, Kurepa hypothesis, Kurepa line, Kurepa space, Kurepa family in set theory, Kurepa-Vandermonde matrices, etc. Prof. Kurepa in 1935 described construction of the Aronszajn tree. It is interesting to notice that this important contribution by Aronszajn was newer published in a paper, and the name and championing of the concept are due to Kurepa and his publications

Kurepa, Dj., "Ensembles linéaires et une classe de tableaux ramifiés (tableaux ramifiés de M. Aronszajn)", *Pub. Math. Univ. Belgrade*, 6, 1937, 129160.

Kurepa, Dj., "Ensembles ordonnés et ramifiés", *Pub. Math. Univ. Belgrade*, 4, 1935, 1138.

Kurepa also introduced the concept of the left factorial in Dj. Kurepa, "On the left factorial function !n", *Math. Balkanica*, Vol. 1, 1971, 147153.

III. Descendant Schools

In this section, we briefly enumerate chief members of the School of Gavrilov, and leading researchers in research groups which originated as descendants of the School of Gavrilov, asking excuses in advance for all possible unintended omissions. The researchers are split into groups with respect to two criteria, the research subjects and the geographical locations of the corresponding research institutions.

Students of M. A. Gavrilov (Institute of Control Sciences, Moscow) - O. P. Kuznetsov, V. D. Kazakov, Yu. L. Tomfeljd, B. L. Timofeyev, V. M. Ostianu, V. F. Ljakhovich, V. V.

[1] R.S. Stanković is proud that Prof. Kurepa was a friendly advisor and a supervisor of him, and the president of the defence committees for his MSc. and Ph.D. theses defences.

Fig. 3. Mikhail Aleksandrovich Gavrilov

Fig. 4. Gellius Nikolaevich Povarov

Fig. 5. Djuro R. Kurepa

Devjatakov, E. I. Pupirev, A. A. Ambartsumyan, A. I. Potekhin, S. A. Stepanenko, L. G. Bivol, A. N. Malevich, E. N. Zapoljskih, A. B. Chichkovsky, B. I. Lipatnikov, S. A. Iskra, L.A. Ivchenkov, L. A. Sholomov, A. Y. Makarevskii, L. B. Shipilina, A. V. Markov, L. A. Vol'vovskii, A. K. Grigoryan, B. Sh. Okudzhava, B. A. Lagovier, I. E. Voeckler, M. J. Zolotarevskaya, E. Galaktionova, E. A. Grebenyuk, S. B. Kotlyar, et al.

Students of V. M. Glushkov, (Institute of Cybernetics, Kyiv), who developed a methodology for synthesis of digital automata and solved the generalized fifth Hilbert problem, -Yu. V. Kapitonova, A. A. Letichevsky, G. E. Tsetlin, A. A. Stogniy, Z. L. Rabinovich, Z. L. Ivaskiv, V. N. Koval, A. N. Chebotarev, L. V. Matsevity, V. P. Derkach, E. L. Denisenko, N. S. Chaika, V. G. Alekseenko, T. Mishchenko, S. S. Gorokhovsky, V. G. Bodnarchuk, E. I. Komuhaev, V. V. Litvinov, et al.

Students of I. V. Prangishvili (Institute of Control Sciences, Moscow) - V. V. Ignatuschenko, V. D. Malyugin, E. V. Babicheva, N. A. Abramova, M. A. Uskach, V. M. Vishnevsky, I. L. Medvedev, G. G. Stetsyura, A. Veitz, V. G. Chachanidze, G. G. Asatiani, T. D. Abuladze, I.P. Egorov, I. A. Stepanovskaya, I. V. Speranskaya, G. M. Popova, O. G. Smorodinova, A. A. Chudin, E. G. Prokhorov, V. K. Bykhovsky, D. V. Pevcov, V. V. Sokolov, M. A. Zuenkov, etc.

Students of V. G. Lazarev (Institute for Information Transmission Problems, Moscow) - E. I. Piilj, V. F. Dyachenko, G. G. Savvin, V. A. Garmash, O. F. Naumchuk (Sergeeva) , G. V. Kreynin, V. M. Isyanov, E. B. Ershova, V. A. Ershov, T. L. Maystrova, O. Ivanova, E. N. Turuta, V. M. Chentsov, A. V. Butrimenko, V. G. Chernyaev, A. G. Saveliev, I. D. Seiful, V. N. Doniants, A. I. Firsov, F. I. Pepinov, E. A. Kondratieva, E. P. Soprunenko, N. Ya. Parshenkov, A. V. Soloviev, G. V. Bogdanova, N. Zoreva , etc.

Students of V. I. Varshavski (Leningrad) - Ya. Rosenblum, B. L. Avsievich, I. M. Bogolyubov, I. P. Vorontsova, V. A. Peschanskii, V. B. Marakhovskii, N. A. Starodubtsev, B. S. Tsirlin, A. V. Kondratyev , M. A. Kishenevsky, A. R. Taubin, A. G. Astanovsky, R. L. Finkelstein, A. V. Yakovlev.

Students of A. D. Zakrevskij (Tomsk State University, Institute of Engineering Cybernetics, Minsk) - A. E. Yankovskaya, Yu. V. Pottosin, A. Yu. Matrosov, V. G. Novoselov, V. F. Rothko, H. R. Toropov, G. P. Agibalov, N. V. Yevtushenko, L. D. Cheremisino. More details of the work by Zakrevskij and his own school can be found at [49], and (is.ifmo.ru/automata/Zakrevsky)

Students of E. A. Yakubaitis (Institute of Automation and Computer Science, Riga) - G. F. Fritsnovich, A. Gobzemis, V. P. Chapenko, V. G. Gorobetc, A. F. Petrenko, A. L. Gurtovtsev, A. Ya. Kalnberzin, E. Ya. Greenberg, I. G. Ilzinya, I. G. Lembersky, E. E. Lange, Ya. Ya. Kalnins, A. Yu. Tolmachev, et al.

Students of D. A. Pospelov - V. N. Zakharov, V. E. Hazatsky, V. N. Vagin, et al.

Students of A. V. Kalyaeva (Taganrog Radio Engineering Institute) - A. N. Melikhov, V. M. Kureichik, L. S. Bernstein, G. I. Ivanov, N. G. Topolsky, V. F. Guzik, O. N. Pyavchenko, V. V. Lisyak, V. I. Kodachigov, O. B. Makarevich, N. I. Vitiska, N. I. Denisenko, V. A. Kalashnikov, et al.

Students of P. P. Parkhomenko (Institute of Control Sciences, Moscow) - V. R. Gorovoj, V. V. Karibskii, E. S. Sogomonyan, G. P. Aksenova, V. F. Khalchev, M. F. Karavai, et al.

Diagnostics related to the theory of automata, was a topic of research of I. V. Kogan, and D. M. Grobman.

Students of V. P. Tchistov (Institute of Mathematics, Sverdlovsk) - V. P. Bityutskii, N. V. Zakurdaev, N. V. Kovalin, I. A. Kononenko, I. O. Sitnikov, M. A. Gogina, etc.

IV. Other research centers in the area

In this section, we enumerate some other research centers working actively at that time in the field. Most of them are active now with efforts of new generations of researchers.

Moscow - M. L. Tsetlin, D. Kharkevich, G. S. Pospelov, R. R. Varshamov, V. N. Roginskii, A. A. Arkhangeljskaya, V. I. Neiman, A. A. Talj, M. A. Aizerman, L. I. Rozenoer, L. A. Gusev, I. M. Smirnov, E. A. Trahtengerts, A. N. Yurasov, E. K. Voishvillo, Y. I. Meckler, V. V. Vorzheva, V. P. Didenko, V. I. Ivanov, A. D. Talantsev, N. P. Vasiliev, Y. L. Shagalovich, V. A. Gorbatov, V. L. Stefanyuk, S. M. Domanickii, V. I. Maksimov, S. A. Yuditskii, A. A. Tagaevskaya, T. K. Efremov, T. K. Berends, I. D. Zaslavsky, J. A. Schroeder, V. M. Ozernoi, N. P. Red'kin, M. G. Millerova, N. N. Ivanov, V. V. Rudnev, G. I. Mikhailov, A. M. Kukinov, M. I. Shamrov, Yu. A. Popov, P. E. Bochkov, Yu. V. Golunkov, E. I. Gurvich, E. A. Gurvitz, E. G. Dulepov, V. M. Karasik, V. L. Beljawskii, A. D. Kazakov, et al.

Leningrad - M. G. Karpovsky, S. I. Baranov, O. F. Nemolochnov, G. R. Firdman, B. G. Pittel, V. V. Sapozhnikov, Vl. V. Sapozhnikov, Ya.G. Karpov, V.L. Artyuhov, G.A. Kopeiikin, A. A. Shalyto, V. N. Kondratiev, G. A. Kuharev, E. S. Moskalev, V. L. Perchuk , V. S. Dudkin, L. Yu. Lapkin, A. N. Berlin, S. D. Aljtschulj, G. I. Gilman, G. I. Rog, E. D. Ioheljson, G. S. Avsarkisyan, I. Levin, etc.

Kiev - E. N. Vavilov, G. P. Tailor, B. P. Egorov, D. B. Shishkov, V. I. Kartashov, S. P. Kartasheva, I. V. Safonov, and others.

Novosibirsk - O. L. Bandman, E. V. Evreinov, G. Kosarev, Y. I. Fet, L. I. Makarov, S. V. Makarov, V. P. Markova, S. V. Piskunov, S. M. Achasova, P. A. Anishev, A. I. Mishin, B.

A. Sedristy, Yu. V. Merekin, S. N. Sergeev, Yu. N. Korneev, A. A. Koifman, V. A. Skorobogatov, V. G. Horoshevsky, I. V. Ilovajskij, A. I. Khrushchev, V. I. Potapov, S. G. Sedukhin, et al.

Minsk - A. Sh. Bloch, V. I. Lades, A. I. Pavlovsky, V. A. Kazuschik, K. V. Ponomarenko, G. V. Neverov, A. V. Gorelik, A. A. Utkin, V. A. Sklyarov, V. N. Sinev, V. P. Shmerko, S. N. Yanushkevich, E. N. Zaitseva, and others.

Yaroslavl - Yu. A. Mamatov

Novocherkassk - M. S. Melnikov

Penza - V. I. Levin

Ryazan - A. P. Koryachko

Riga - I. E. Strazdin, A. N. Sklyarevich, V. L. Bielawski

Vladivostok - V. P. May, G. R. Greiner, R. S. Goldman, V. P. Chipulis, L. I. Tokmakova

Donetsk, Saratov - A. M. Bogomolov, D. V. Speransky, A. S. Barashko, I. S. Grunskii, V. A. Kozlovsky, A. A. Barkalov, V. A. Tverdohlebov, et al.

Kishinev - V. Z. Krištal, M. S. Bulat

Tallinn - R. Ubar, B. G. Tamm, E. H. Tyugu, H. I. Tanya, A. E. Keevalik

Uzhgorod - N. N. Aizenberg

Sevastopol - E. A. Butakov, V. I. Ostrovsky

Frunze - V. V. Obrazovc, Yu. N. Arsentiev, V. M. Kopylenko, T. G. Bazarbaeva, Z. I. Vostrova,

Tbilisi - V. V. Chavchanidze, A. H. Giorgadze, G. A. Ananiashvili, G. S. Tsiramua

Baku - R. H. Faradzhev, Askerov Charles, I. V. Hamidov

Kaunas - Abraytis L. B., Atstopas F. F., Zhintelis G. V., et al.

Tashkent - D. A. Abdulaev, D. Yunusov

Kharkiv - V. A. Popov, I. T. Skibenko, I. G. Moklyak, A. V. Sychev, V. A. Mishchenko, V. D. Kozyuminsky, A. N. Semashko, et al.

Tiraspol - V. S. Vykhovanets

V. Researchers in Related Areas in USSR

Note that many other scientists worked in the field of applied theory of automata. They are not mentioned above since do not participate in the work of the School of Gavrilov. At that time, S. A. Mayorov, G. I. Novikov, V. I. Skorubsky, V. B. Smolov, D. V. Puzankov, E. P. Balashov, G. A. Petrov, B. V. Barashenkov, M. B. Ignatyev, V. A. Torgashev, L. Y. Kravtsov, B. P. Kuznetsov, and many others actively worked.

In research on theory of probabilistic automata R. G. Bukharaev, V. G. Sragovich, G. N. Tsertsvadze, A. Lorenz, Yu. A. Flerov, M. K. Chirkov, V. V. Novorusskii, et al., were involved.

Besides research in applied theory of automata, in the USSR there was a school of mathematicians studied the theory of automata, which worked mainly at the Institute of Applied Mathematics, USSR Academy of Sciences (Moscow) and the Moscow State University and has had a significant impact on the applied theory of automata and professionals working in this field.

The leader of this school O.B. Lupanov is still active (wikipedia.org/Lupanov). The summary of his PhD thesis occupies a little more than a page, instead being just a recording sheet, as usually happens.

At the defense, Lupanov presented a proof of the asymptotic estimate of complexity of the minimal network realizing an arbitrary Boolean function, which reduced the similar estimate of C. E. Shannon to a half. The author of this reminiscences (Anatoly A. Shalyto), had the honor to talk with O. Lupanov, and this conversation he will remembered for a lifetime. Shalyto recalls

Although without a preliminary agreement, the conversation started in 22.15 hours, and ended well after midnight. The conversation was at the Hills of Lenin in the winter and on the cold weather, and it was necessary to return to home after the talk. In spite of all these inconvenient circumstance, and although being among most renowned authors in discrete mathematics, and seeing me for the first time [2]*, Lupanov listened to me carefully and with no hurry.*

Another interesting issue. At an occasion, I talked about the anniversary of Lupanov with my supervisor V. L. Artyukhov, who wrongly supposed that Oleg Borisovich is in age of eighty, instead of just fifty, because Lupanov was already so widely known for many years.

Students of this school also included S. V. Yablonsky, Yu. I. Zhuravlev, I. A. Chegis, G. Potapov, Yu. L. Vasilyev, A. D. Korshunov, R. V. Freivald, V. V. Martyniuk, G. A. Shestopal, Yu. T. Medvedev, V. I. Lowenstein, G. P. Gavrilov, and V. B. Kudryavtsev, S. V. Aleshin, A. S. Podkolzin, N. A. Karpova, V. M. Khrapchenko, V. A. Buevich, A. A. Karatsuba, M. I. Kratko, V. N. Redko, A. V. Kuznetsov, A. A. Sapozhenko, B. A. Subbotovskaya, etc.

In addition, in Moscow at that time such well-known scientists in the field of discrete mathematics and artificial

[2] I should confess, that Lupanov had in his bookshelf my book that I sent him a bit earlier.

intelligence as A. S. Adian, V. A. Uspensky, M. A. Kronrod, G. M. Adelson-Velskii, and E. M. Landis worked. The concept of AVL-trees and Evgenii Landis trees are studied all over the world in courses related to the theory of algorithms. V. L. Arlazarov, A. Uskov, L. G. Khachiyan, proposed a polynomial algorithm for linear programming. Then, there B. C. Zaripov, and many others were working.

In Novosibirsk, in the automata theory and discrete mathematics B. A. Trakhtenbrot, N. E. Kobrin, Yu. L. Ershov, A. V. Gladki, V. A. Kuzmin, V. V. Glagolev, M. I. Kratko , R. E. Krichevskii, V. A. Evstigneev, et al. worked.

In this area in Riga, Y. M. Barzdin, in Kazan - R. G. Nigmatullin. In Leningrad studies in mathematical logic performed N. A. Shanin, Yu. V. Matiyasevich, who solved the tenth Hilbert problem, S. Yu. Maslov, A. O. Slisenko, G. S. Tseitin worked, and in theory of automata E. I. Nechiporuk [3], and A.G. Luntz.

Research on automata theory in the USSR have been carried out in parallel with the development of practical and theoretical programming. In establishing of it involved were renowned scholars, such as A. A. Abramov, A. L. Brudno, Yu. I. Yuanov, A. P. Ershov, V. P. Ivannikov (chief editor of the journal "Programming"), M. R. Shura-Bura, R. I. Podlovchenko, O. S. Kulagina, S. S. Lavrov, I. B. Zadihailo, E. Z. Lyubimskii, L. A. Lyusternik, S. S. Kamynin, L. A. Kaluzhnin, V. V. Martynyuk, N. P. Trifonov, E. A. Zhogolev, V. F. Turchin, V. I. Shestakov, V. S. Shtarkman, E. L. Yushchenko, V. S. Koroljuk , V. N. Agafonov, I. V. Pottosin, V. N. Kasyuanov, V. A. Nepomnyashchii, V. E. Kotov, V. K. Sabelfeld, A. S. Narinyani, V. A. Valkovskii, etc.

Work on the theory of automata and programming was used indirectly and directly in the design of national computer technology, some examples of which (for example, the machine M-10 and BESM-6) are not inferior, and in many respects, superior to their foreign counterparts. It is primarily true for classified devices, as otherwise the Soviet Union could not provide a defense parity. Among the founders of domestic computer technology should be noted such outstanding designers as S. A. Lebedev, J. S. Brooke, B. I. Rameev (who become a Doctor of Technical Sciences without higher education), N. I. Bessonov, Y. Y. Bazilevskii, N. Y. Matyuhin, N. P. Brusentsov, L. N. Korolev, M. A. Kartcev, N. G. Bruevich, B. N. Malinovsky, B. V. Bunkin, V. S. Burtsev, V. A. Melnikov, B. A. Babayan, et al.

Automata Theory, Programming, and Computer Science have developed in the framework of a single direction, called by N. Wiener "Cybernetics" (now viewed as the "Informatics" or "Computer Science"), which was also characterized by consideration of wildlife management. This area was studied by N. V. Timofeev-Resovskii, I. I. Shmal'gauzen, A. R. Luria, V. S. Gurfinkel, and many others.

The role of A. I. Berg, M. G. Gaase-Rapoport, A. A. Dorodnicyn, V. A. Kotelnikov, B. V. Gnedenko, N. P. Buslenko, R. L. Dobrushin, M. M. Bongard, I. A. Poletaeva, A. I. Kitov, N. A. Krinitsky in the development of cybernetics in the USSR cannot be overestimated.

Many of these experts mentioned above are renowned scientists at the world level, but in addition to them, the development of cybernetics in our country was supported and contributed by such giants of science as L.V. Kantorovich, M. V. Keldysh, M. A. Lavrent'ev, S. L. Sobolev, P. S. Novikov, A. A. Markov (Jr.), I. M. Gelfand, A. I. Maltsev, A. A. Lyapunov (wikipedia.org/Lyapunov), (www.prometeus.nsc.ru/Lyapunov/).

A few words of Alexei A. Lyapunov (1911-1973), a student of N. N. Luzin, who made a great contribution to the development of theoretical programming in the world.

Alexei Andreyevich conducted lectures for students of the Moscow State University, the Department of Computational Mathematics, in the 1952-53 academic year a short course entitled "Principles of programming" consisting of just eight lectures. From this course, later courses were developed on symbolic programming languages, compilers (called earlier as programming programs) and the theory of program schemes. Alexei began his course when programmers were rare, there were not many of them, and all the work related to electronic computers was classified. A direct acquaintance of Alexei A. with the first domestic computer machine, created under the leadership of S. A. Lebedev in Feofaniya that is near Kiev, was considerably useful in solving fundamental problems of future programming, see, Podlovchenko (www.mathnet.ru/Podlovchenko).

By the way, a small world, one of the book publishers asked a professor of Moscow State University, Rimma Ivanovna Podlovchenko, to give feedback on the outline of a book "Automata-Based Programming", written by A. A. Shalyto in collaboration with N. I. Polikarpova.

Turning to the review of the achievements of Lyapunov, we note first of all his work on the theory of programming. Already in the early days of programming, we have been aware of the difficulties in creating large programs without drawing the appropriate flowchart in terms of fairly large operations. In 1953, Alexei proposed a method for preliminary description of programs in terms of operator schemes, which was focused on a clear allocation of the main operators and to build a kind of algebra transformation programs. This method, due to the usage of algebraic expressions, was much more convenient than the previously applied method of flowcharts. It has become the primary means of automatization of programming and is the basis of the ideas of the Soviet school of programming. These ideas were further explored and improved by the Soviet (Yu. I. Yanov, A. P. Ershov) and foreign scientists. In this way a better understanding was achieved of how to deal with flow graphs of programs in an equivalent manner and to evaluate the resulting programs in view of their logical flow graphs" (B. Trakhtenbrot).

VI. Instead of Conclusions

IEEE (The Institute of Electrical and Electronic Engineers) as the international community exists for over 100 years. In

[3] See, Stanković, R. S., Astola, J. T., (eds.), *Reprints from the Early Days of Information Sciences, On the Contributions of E. I. Nechiporuk to Switching Theory*, TICSP # 36, 2007, ISBN 978-952-15-1788-4

1946, it was established a structural unit - the Computer Society, which brings together hundreds of thousands of professionals working in the field of computer science and industry: computer science, programming, production of computer equipment, and computer business. The most prestigious award of the society, the medal "Computer Pioneer", was established in 1981. Its purpose is to recognize and present to the world community the outstanding individuals whose efforts created and developed computer technology, provided that their main contribution was made at least 15 years ago. Among the 55 winners of this prestigious award, there are such classics of computer science, as John Atanasov, for creating one of the first electronic computers, Nicolaus Wirth, for the development of language "Pascal", George McCarthy and Marvin Minsky, for the work in the field of artificial intelligence, E. Kodd, for inventing the relational data model and others.

In this list (considerably because of the Iron Curtain) there were not Soviet scientists. In 1996, at the fiftieth anniversary of its establishment, the Computer Society make a great effort to restore historical justice, and awarded by medals "Computer Pioneer" V. M. Glushkov, S. A. Lebedev, and A. A. Lyapunov, for achievements in establishing foundations of Computer Engineering and Programming" (G. V. Karatkevich).

In addition, note that the formulation of automata theory and the theory of programming happened in the pre-Internet era place, which virtually eliminates results obtained in these areas from the sphere of interests of Russian youth, for which the Internet is almost the only source of knowledge. Although this trend still does not swept the whole world, for example, the Cambridge University Library subscribes to 55,000 magazines (!) that are probably read ("Izvestia", of 19.04.2002).

A list of publications of Soviet Union researchers in first 20 years of Switching Theory and Logic Design can be found in [45]. Comprehensive and very informative reviews of the School of Gavrilov can be found in [16], [27].

REFERENCES

[1] Anellis, I. H., "Mathematical logic in the Soviet Union, 1917 - 1980", *History and Philosophy of Logic*, Vol. 8, No. 1, 1987, 71-76.

[2] Anellis, I.H., *Sofya Aleksandrovna Yanovskaya's Contributions to Logic and History of Logic*, Modern Logic Publishing, USA, 1996.

[3] Artyukhov V.L., Kondrat'ev V.N., Shalyto A.A., "Generating Boolean functions via arithmetic polynomials", *Automation and Remote Control*, Vol.49. No. 4, 1988, 508-515.

[4] Bažanov, V.A, "V.I. Shestakov and C. Shannon - Different fates of one brilliant idea authors", *Voprosy Istorii Estestvoznaniya i tehniki*, No. 2, 2005, 112-121.

[5] Bažanov, V.A., *History of Logic in Russia and the USSR - Conceptual Context of University Philosophy*, Canon+, Moscow, 2007.

[6] Couturat, L., *L' algebre de la logique*, Paris 1905, 100 pages, 2nd. edn., Paris 1914, 100 pages. Hungarian translation *A logika algebraja*, translated by Denes Konig, Mathematikai es physikai lapok, Budapest, Vol. 17, 1908, 109-202, Russian translation *Algebra logiki*, Mathesis, Odessa, 1909, iv+l07+xii+6. English version *The Algebra of Logic*, The Open Court Publishing Company.

[7] Ehrenfest, P. , "Review of L. Couturat, *Algebra of Logic*", *Zhur. Russ. Fiz.-Khim. Obshchestva, fiz. otdel (J. Russ. Phys. Chem. Soc. Phys. Sec.)* Vol. 42, Sec. 2, No. 10, 1910, 382-387.

[8] Janovskaja, S.A., "Mathematical logic and foundations of mathematics", *Mathematics in SSSR for* 40 *years 1917-1957*, Vol. 1, Moscow, 1959.

[9] Kautz, W.H., "A survey and assessment of progress in switching theory and logical design in the Soviet Union", *IEEE Transactions on Electronic Computers*, Vol. EC-15, No. 2, April 1966, 164-204.

[10] Kondratiev, V.N., Shalyto, A.A., "Realizations of a system of Boolean functions by using linear arithmetic polynomials", *Automatika and Telemekhanika*, No. 3, 1993, 135-151, English translation: *Automation and Remote Control*, Vol. 54, No. 3, 1993, 472-488.

[11] Kondratiev, V.N., Shalyto, A.A., "Realizations of a system of Boolean functions by a single arithmetic polynomial with masking", *Automatika and Telemekhanika*, No. 1, 1996, 158-170, English translation: *Automation and Remote Control*, Vol. 57, No. 1, 1996, 127-137.

[12] Kondratiev, V.N., Shalyto, A.A., "Realizations of a system of Boolean functions by linear arithmetic polynomials", *Automatika and Telemekhanika*, No. 3, 1997, 200-215, English translation: *Automation and Remote Control*, Vol. 58, No. 3, 1997, 492-503.

[13] Kung, G., "Bibliography of soviet work in the field of mathematical logic and foundations of mathematics from 1917-1957", *Notre Dame Journal of Formal Logic*, Vol. 3, No. 1, January 1962, 1-40.

[14] Kung, G., "Mathematical logic in the Soviet Union, 1917-1947 and 1947-1957", *Studies in Soviet Thought*, Vol. 1, No. 1, 1961, 39-43.

[15] Kurepa, G., "Sets-logics-machines", *Proc Int. Symp. Theory of Switching*, Harvard University, Cambridge, Mass., Pt. 1, April 1957, 137-146.

[16] Kuznetsov, O.P., *Mikhail Aleksandrovich Gavrilov*, History of Informatic in Russia: Scientists and their Schools, Moscow, Nauka, 2003, 88-97, (in Russian), www.computer-museum.ru/books/IKT-schools/Kuznetsov.

[17] Levin, V. I., Victor Ivanovich Shestakov and the history of discovery of logical modelling in technics, *Izvestija penzenskogo gosudarstvennogo universiteta pedagogiceskogo universiteta im. V. G. Belinskogo*, No. 23, 2011, 459-504.

[18] Malyugin, V.D., "Switching circuits reliability", *Automatics and Telemechanics*, Vol. 25, No. 9, 1964, 1375-1383.

[19] Malyugin, V.D., *Elaboration of theoretical basis and methods for realization of parallel logical calculations through arithmetic polynomials*, Ph.D. Thesis, Inst. of Control Sciences, Russian Academy of Science, Moscow, 1988.

[20] Malyugin, V.D., *Paralleled Calculations by Means of Arithmetic Polynomials*, Physical and Mathematical Publishing Company, Russian Academy of Sciences, Moscow, 1997, (in Russian).

[21] Malyugin, V.D., Kukharev, G.A., Shmerko, V.P., "Transforms of polynomial forms of Boolean functions", *Inst. of Control Sciences*, Moscow, 1986, 1-48.

[22] Malyugin, V.D., Sokolov, V.V., "Intensive logical calculations", *Avtomatika and Telemekhanika*, No. 4, 1993, 160-167.

[23] Malyugin, V.D., Veits, A.V., "Intensive calculations in parallel logic", *Proc. 5th Int. Workshop on Spectral Techniques*, 15.-17.3.1994, Beijing, China, 63-64.

[24] Merekin, Y.V., "Arithmetical forms of Boolean expressions and their applications in network reliability calculations", Inst. of Mathematics, SOAN SSSR, 1963.

[25] Peirce, Ch., "On the Algebra of Logic - A contribution to the philosophy of notation", *American Journal of Mathematics*, 7, two parts, first part published 1885, 180202.

[26] Pospelov, D. A., "Establishment of information science in Russia", in D. A. Pospelov, Y.I. Fet "Essays on history of Computer Science in Russia", Novosibirsk, published by OO GGM SO Siberian Department of the Academy of Sciences Russia, 1998.

[27] Pospelov, D.A., *School of MAG*, History of Informatic in Russia: Scientists and their Schools, Moscow, Nauka, 2003, 98-110, (in Russian), www.computer-museum.ru/books/IKT-schools/Pospelov.

[28] Povarov, G.N., "Logic, Automation and Computing - Rise of Russian Technical Logic", in G. Trogemann, A.Y. Nitussov, W. Ernst (Eds.), *Computing in Russia*, Vieweg, Wiesbaden, 2001.

[29] Shalyto, A.A., *Logic Control - Methods of Hardware and Software Implementation*, Nauka, Moscow, Russia, 2000, 780 p., (in Russian).

[30] Shalyto, A. A., "It was a Great epoch in our (Russian) scientific community", first edition, 2002, ITMO Univeristy, http://is.ifmo.ru/belletristic/pre/

[31] Shalyto, A. A., "It was a Great epoch in our (Russian) scientific community", second edition, 2002, Virtual Computer Museum, http://www.computer-museum.ru/histsoft/epoch.htm

[32] Shalyto, A. A., "It was a Great epoch in our (Russian) scientific community", *Informaton and Control Systems*, No. 1, 2003, 52-56 (in Russian).

[33] Shannon, C.E., "A symbolic analysis of relay and switching circuits", Transactions of the American Institute of Electrical Engineers, Vol. 57, 1938, 713-723.

[34] *Synthesis of electronic calculation and control networks*, translation from English under supervision by B.I. Shestakov, Izd. Inostranoi Literaturi, Moscow, 1954.

[35] Shestakov, V. I., "Some Mathematical Methods for the Construction and Simplification of Two-Terminal Electrical Networks of Class *A*", PhD Dissertation, defended on September 28, 1938, at The Lomonosov State University, Moscow, Russia, 1938.

[36] Shestakov, V. I., "Algebra of two terminal networks constructed exclusively of two terminal elements (Algebra of *A*-networks)", *Zhur. Tekh. Fiz.*, Vol. 11, No. 6, 1941, 532-549, *Avtomat. i Telemekh.*, No. 2, 1941, 15, (In Russian), *J. Simbolic Logic*, Vol. 21, 1941, 399, (Review).

[37] Shestakov, V. I., "The algebra of two-terminal networks constructed exclusively of two-terminal elements (The algebra of A-networks)", *Avtomatika i Telemekhanika*, Vol. 2, No. 6, 1941, 15-24.

[38] Shestakov, V. I., "A symbolic calculus applied to the theory of electrical relay networks", Ucenye Zapiski Moskowskog Gosudarstvenog Universiteta, Vol. 73, No. 5, 1944, 45-48.

[39] Shestakov, V. I., "The representation of the characteristic functions of propositions by means of expressions which are realized by relay-contact networks", Izv. Akad. Nauk., Ser. Matem., Vol. 10, 1946, 529-554.

[40] Shestakov, V.I., "A dual arithmetic interpretation of the 3-valued propositional calculus utilized in the simulation of this calculus by relay-contact networks", *Appl. Logic in Sci. Tech.*, 1960, 341-367, (in Russian).

[41] Shestakov, V. I., "On the relationship between certain three-valued logical calculi", *Uspehi Mat. Nauk*, Vol. 19, No. 2 (116), 1964, 177-181. Also see *Math. Reviews*, 31, 1966, #2140.

[42] Stanković, R.S., Astola, J.T., *Reprints from the Early Days of Information Sciences, On the Contributions of P.S. Poreckij to Switching Theory*, Tampere International Cnter for Signal Processing, Tampere University of Technology, Tampere, Finland, TICSP #46, 2009, ISBN 978-952-15-2052-2

[43] Stanković, R.S., Astola, J.T., *Reprints from the Early Days of Information Sciences, On the Contributions of Akira Nakashima to Switching Theory*, Tampere International Cnter for Signal Processing, Tampere University of Technology, Tampere, Finland, TICSP #40, 2008, ISBN 978-952-15-1980-2.

[44] Stanković, R.S., Astola, J.T., (eds.), *Reprints from the Early Days of Information Sciences, Paul Ehrenfest - Remarks on Algebra of Logic and Switching Theory*, Tampere International Cnter for Signal Processing, Tampere University of Technology, Tampere, Finland, TICSP #54, 2010, ISBN 978-952-15-2419-6.

[45] Stanković, R.S., Astola, J.T., Shalyto, A.A., Strukov, A.V., *Reprints from the Early Days of Information Sciences, Early Work in Switching Theory and Logic Design in USSR*, Tampere International Cnter for Signal Processing, Tampere University of Technology, Tampere, Finland, TICSP #66, 2016, ISBN 978-952-15-3786-8.

[46] *The Annals of the Computation Laboratory of Harvard University*, Volume XXVII, *Synthesis of Electronic Computing and Control Circuits*, Cambridge, Massachusetts, USA, 1951.

[47] Vucinich, A., "Mathematics and dialectics in the Soviet Union - the pre-Stalin period", *Historia Mathematica*, Vol. 26, 1999, 107-124.

[48] Yamada, A., History of research on switching theory in Japan, *IEEJ Trans. Fundamentals*, Vol. 124, No. 8, 2004, 720-726, (in Japanese).

[49] Zakrevskiy, A.D., Prangishvily, I.V., (Eds.), *Theory of Discrete Control Devices*, Moscow, Nauka, 1982.