

BORIS TEODOROVICH POLYAK

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Abstract

In the paper, a brief history of life and work of the celebrated Russian mathematician Boris Teodorovich Polyak is exposed. The list of Polyak's main publications is given.

Boris Teodorovich Polyak (1935-2023) was an outstanding Russian scientist in the field of optimization and control theory. Boris Polyak was born on May 4, 1935 in Moscow, where he lived all his life.

In 1958 he graduated from the Moscow Institute of Steel and Alloys (MISiS), diploma practice was held at the Central Research Institute of Ferrous Metallurgy (TsNIICherMet), dealing with the calculation of the process of continuous casting of steel using a mathematical model in the form of equations in partial derivatives with moving boundary and non-standard boundary conditions. Notably, analytical methods did not work in this problem. When writing his thesis, student Polyak for the first time took up programming on one of the first computers in the USSR "M-2" in the Laboratory of Control Machines and Systems (LUMS) of the Energy Institute of the USSR Academy of Sciences (ENIN). A unique fact is that Boris Polyak's first program worked correctly immediately (needed no debugging).

After graduating from MISiS, Boris Polyak got a job at ENIN, first in the department for the hardware development, in particular, the development of ferrite memory for computers, and then moved to the department for mathematicians-programmers, working with outstanding researchers A. Kronrod, A. Brudno, G. Adelson-Velsky, A. Lunts, E. Glivenko, who have formed the foundations of the USSR computer science in those years. They also have formed young Polyak's way of thinking and way of life. As he wrote in his memoirs, "For me, being in this free-spirited community was crucial to my choice of behavior, and I remain grateful for a lifetime"¹ Thus, the young research physicist turned into a specialist in the field of cybernetics. One of the tasks,

the solution of which was already programmed by Boris Polyak, was tracking and forecasting the motion of a ballistic missile over a series of successive error-corrupted measurements of its trajectory. Such tasks have probably allowed Boris to understand an importance and significance of the effective implementation of numerical optimization methods under conditions of significant uncertainties which significantly affected his scientific carrier.

After working at ENIN, Boris Polyak entered the graduate school of the Faculty of Mechanics and Mathematics of Moscow University (MGU) and graduated from it in 1963. In 1964 he defended his Ph.D. thesis on the topic "Gradient methods for minimizing functionals, solutions of equations and inequalities". Worked as a junior, then a senior researcher at the Computing center of Moscow University. In 1968, he had to leave Moscow State University after he signed a protest letter of more than 90 mathematicians ("letter of the 99") in support of the famous mathematician and human rights activist A.S. Yesenin-Volpin.

From 1971 until the last days he was with the Institute of Control Science of the USSR Academy of Sciences (later RAS) in the positions of senior, leading, chief researcher in laboratory No. 7 under the supervision of Academician Yakov Tsyppkin. In 1978 he defended his doctoral thesis on the topic "Optimization methods in the presence of uncertainties". From 1997 to 2013 he headed the laboratory "Adaptive and robust systems named after Yakov Tsyppkin" at IPU RAS. In recent years, Boris Teodorovich Polyak was also a professor at the Moscow Physics and Technology Institute and chief researcher at the IPU RAS.

The breadth of scientific interests and productivity of B.T. Polyak are amazing. He was the author of six monographs, 220 articles in journals and over two hundred papers in Russian and international conferences in the

¹A page of B.T.Polyak's memoirs about his first steps in science (in Russian) <https://7i.7iskusstv.com/y2020/nomer7/bpoljak/>

following scientific fields:

- Mathematical programming
- Convex analysis and duality in non-convex problems
- Numerical methods
- Stochastic approximation
- Estimation and identification
- Stochastic optimization
- Optimal control
- Robust stability
- Robust control
- Chaos control
- Randomized methods
- D-decomposition
- Linear matrix inequalities
- Ellipsoidal state estimation
- Attenuation of bounded external disturbances
- Sparse control
- Peak phenomenon
- Relationship between optimization problems and stability problems
- Optimization approach to control design.

Boris Teodorovich was one of the most famous Russian scientists in the fields of optimization and control. His monograph “Introduction to Optimization” went through three editions in the USSR and Russia, (Moscow, Nauka, 1983, 384 pp.; 2nd ed. Moscow, URSS, 2014; 3rd ed. Moscow, URSS, 2019) and was translated into English (Introduction to Optimization. New York, Optimization Software, 1987). Until now, it is a reference book for many specialists and is used in teaching students all over the world.

He was the Deputy Editor-in-Chief of the journal “Automatika and Telemekhanika” (translated into English as “Automation and Remote Control”) and a member of the editorial boards of nine international and Russian journals, member of several dissertation and scientific councils, served on the Program Committees of many international conferences.

He was the founder of the Traditional Youth Schools “Control, Information and Optimization” which came to be known as the “Polyak School”. He also chaired the Organizing Committee of the first ten schools.

B.T. Polyak was a member of the Technical Committee TC 2.5 of the International Federation for Automatic Control (IFAC), Chairman of the Commission on Signals and Systems of the Russian National committee on automatic control, headed the section “Control, Stability and Process Optimization” of the Scientific Council on the Theory of Control Processes and Automation of the Russian Academy of Sciences. He was elected an honorary member of IFAC (IFAC Fellow) in 2006 and he was first in Russia to receive this award. He was the winner of a number of prestigious Russian prizes and awards (Andronov prize of RAS, 1994, 2014; Letov prize (1999, 2010); Kulebakin prize, 2004; Tsympkin prize, 2005; Feldbaum prize, 2006, as well as inter-

national awards including:

- European Association for Operations Research Gold Medal EURO-2012;
- Khachiyan Award of the INFORMS Optimization Society, 2021.

Boris worked at the universities in the USA, France, Italy, Israel, Mexico, Taiwan, Finland and other countries. More than 25 of his students are candidates and doctors of sciences.

Many of his results have become a part of the gold fund of the world science²:

- Heavy ball method, which became the forerunner of many modern accelerated / moment methods of convex optimization [Polyak, 1964] — 1306 citations (more than 1000 of them were made during the last five years, mainly from the area of machine learning);
- Polyak’s conjugate gradient method [Polyak, 1969a] — 807 citations;
- Methods of gradient minimization of functionals [Polyak, 1963] — 99 citations;
- Constrained minimization methods [Levitin and Polyak, 1966] — 450 citations;
- Polyak-Shor step in gradient descent for non-smooth optimization problems [Polyak, 1969b] — 344 citations;
- Projection method for finding a common point of convex sets [Gubin et al., 1967] — 541 citations;
- Polyak-Ruppert-Juditsky method of step selection and averaging [Polyak and Juditsky, 1992] - 943 citations;
- New improvements of classical Newton’s method [Nesterov and Polyak, 2006] — 417 citations, [Polyak, 2007] — 85 citations;
- Polyak-Lojasiewicz gradient dominance condition, (one of the relaxations of the notion of strong convexity most in demand today) [Polyak, 1963] — 99 citations;
- Convergence and convergence rate of adaptation and stochastic optimization algorithms — [Polyak and Tsympkin, 1973] — 298 citations in Google Scholar, [Poljak and Tsympkin, 1980] — 261 citations in Google Scholar; [Polyak, 1976] — 192 citations in Google Scholar;
- Tsympkin-Polyak frequency-domain robustness criterion [Tsympkin and Polyak, 1991] — 77 citations;
- Robust Nyquist criterion [Polyak and Tsympkin, 1992] - 52 citations in Google Scholar;
- Generalizations of the S-lemma on duality in non-convex extremal problems [Polyak, 1998] — 142 citations;

²The authors thank Pavel Scherbakov for his important comments and Boris Andrievsky for extraction of citation numbers from Scopus on June 21, 2023.

- Ellipsoidal state estimation [Polyak et al., 2004] — 218 citations, [Durieu et al., 2001] — 217 citations;
- Method of invariant ellipsoids [Nazin et al., 2007] — 105 citations, [Polyak and Topunov, 2008] — 70 citations; [Khlebnikov et al., 2011] — 50 citations;
- Probabilistic robustness criteria [Polyak and Tempo, 2001] — 139 citations, [Calafiore and Polyak, 2001] — 110 citations;
- Robust D-decomposition (D-partition) [Gryazina and Polyak, 2006] — 121 citations, [Gryazina et al., 2008] — 79 citations;
- Sparse feedback design [Polyak et al., 2013] — 88 citations, [Polyak et al., 2014] — 25 citations.

Some of these results have become especially popular in recent years due to explosion of the research activities in artificial intelligence and machine learning area.

B.T. Polyak has always taken a principled position on current public problems. He showed his students and colleagues an example of active and principled behavior, honesty and dignity. He was respected and loved by many in Russia and in the world.

B.T. Polyak passed away on February 3, 2023 in Moscow at the age of 87.

Monographs authored or coauthored by B.T. Polyak:

Introduction to Optimization. Moscow, Nauka, 1983, 384 pp.; 2nd ed. Moscow, URSS, 2014; 3rd ed. Moscow, URSS, 2019), translated into English (Introduction to Optimization. New York, Optimization Software, 1987);

Robust stability and Control. Moscow, Nauka, 2002, 303 pp.; 2nd ed. Moscow, URSS, 2014. (together with P.S. Shcherbakov);

Randomized Estimation and Optimization Algorithms under Almost Arbitrary Noise. Moscow, Nauka, 2003, 292 p. (together with O.N. Granichin);

Control of Linear Systems under External Disturbances: Technique of Linear Matrix Inequalities. Moscow, URSS, 2014, 560 p. (together with M.V. Khlebnikov and P.S. Shcherbakov);

Mathematical Theory of Automatic Control. Moscow, URSS, 2019, 500 p. (together with M.V. Khlebnikov and L.B. Rapoport).

Page of memoirs about B.T. Polyak (eng) <https://memorialsource.com/memorial/polyak>.

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