MIKHAIL ANDREEVICH FEDOTKIN: A NONSTATISTICAL ANALYSIS OF THE FIRST 80 YEARS OF HIS LIFE

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Abstract

Professor of the Lobachevsky University of Nizhni Novgorod celebrated his 80th anniversary in May, 2021. This paper touches some of his personal histories, and his scintific contributions.

Keywords: biography, M.A. Fedotkin, applied probabillity school in Nizhni Novgorod

This paper is dedicated to the life and scientific achievements of Mikhail Andreevich Fedotkin, on the occasion of his 80th anniversary. It is not an easy task to present the topic better than the protagonist did himself in his autobiographical book [1]. No one has a more complete knowledge of his life facts than he does. So, we may only revew several turning points in his biography, maybe in a half-joking tone sometimes, with all our love and respect to the man of the hour.

1. His life

May, 1th, 1941 was Thursday. Soviet Union was celebrating the May Day. Official governemental 'Pravda' newspaper reported about achievements of Soviet oil workers in socialist emulation. Workers of the V.V. Kuybyshev Locomotive Factory at Kolomna fulfilled the four-month norm at 109,6 percents. Vasily Smyslov recieved a USSR grandmaster rank from All-nion Committee for physical culture and sports. There are also summaries of the German commans on the sinking of convoys, reports by Reuters about evacuation of a part of Plymouth, on the actions of British aviation, reports on military operations in Africa and the Mediterranean Sea.

Figure 1: *Kulikovo Field surroundings, former Tuzhilki village and Kiselevka village marked with crosses in the bottom -right corner*

On the May Day, 1941 a child was born to Andrei Artemyevich and Ksenia Prokofievna Fedotkin. He was the seventh child in the family. He was named Mikhail.

His birthplace, Kiselevka village, lies in Central Russia, 400 kilometers to the south of Moscow, in the rich-soiled 'chernozem' fields. Not far from the place we find the famous historical Kulikovo Field (where the battle of Kulikovo took place on September, 8, 1380 between the armies of Golden Horde and joint Russian prinipalities under the command of Prince Dmitry Donskoy), Yasnaya Polyana (an estate where Leo Tolstoy lived and wrote his famous masterpieces like 'War and Piece' and 'Anna Karenina'), and Konstantinovka village (where Sergei Yesenin was born, on of the most popular and well-known poets of the 20th century).

The place and epoch definitely influenced his life. He'd got interested in the game of chess and begged his elder brother to get him a set of pieces and a chessboard, he still keeps chessbooks on his bookshelves, and he solves chess compositions easily in his 80. The blazing war in Europe killed his father in 6 months after his birth, and the burden of his large family survival fell on his 36-years old mother. That issue of 'Pravda' oracular. And the region was unique: together with his school teacher and his classmates he went to old villages in the area to search for new historical knowledge about his birthplace. One of the villages was Lyapunovka. Later, using this data, he would reconstruct the genealogy of Lyapunov family who gave not only world-famous mathematician A.M. Lyapunov, but also several other renowned statesmen, scientists, doctors, and music-writers. Fedotkin even hipothesized a missing link in the family tree [1].

What else might have influenced his life trajectory? If one looks at Mikhail's natal horoscope just for fun, he will discover that almost all planets are in the constellation of Taurus together with the Sun, and only the Mars planet is in Aquarius. Astrology books claim that Mars in Aquarius signifies a searching man, eager for new approaches to even traditional problems. Aspiration to bring together like-minded people, his confederates, to give them an interesting task, challenging problems, to administrate them and equip with the necessary amenities. Should we trust this elder form of data-science? A quick check using a computer astronomy program shows that Mars was in Capricorn rather than in Aquarius that moment of time. But what is surprising, this characteristic of a 'Mars in Aquarius' fits Mikhail Fedotkin quite nicely.

He went regulary by feet to elementary school in Tuzhilki, a village at distance of 4 kilometers from Kiselevka. The school occupied the house which used to belong to Fedotkins family more than 10 years before that and now no more. After graduation from school in 1958 he finally enrolls to the Gorky State University. That year a novel educational program 'computational mathematics', focused on cybernetics and use of computers, was opened in the university's department of physics and mathematics.

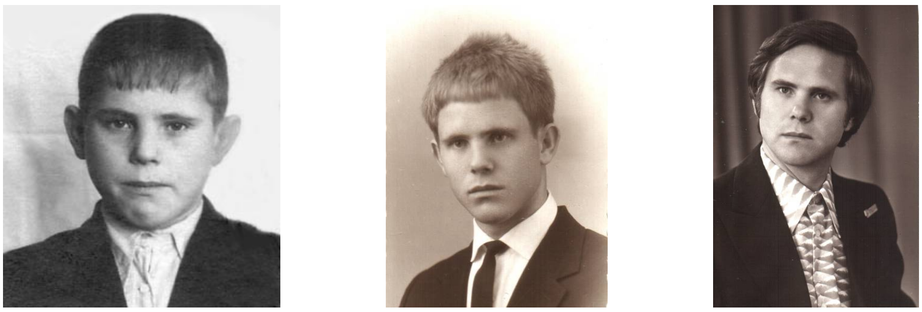

Figure 2: *At age of 7 y.r. (on the left), 17 y.o. (in the middle), 27 y.o. (on the right)*

In 1963 he was graduated from Gorky State University with diploma in mathematics and went to graduate school to specialize in theoretical cybernetics under the supervision of Yuri Isaakovich Neimark, one of the co-founders of the Research Institute for Applied Mathematics and Cybernetics (NII PMK in Russian) of the Gorky State University, and of the Department of Computational Mathematics and Cybernetics (1963). It was the first department of cybernetics in the Soviet Union. For example, the Moscow State University opened a similar department only 10 years later.

In his graduate research M.A. Fedotkin developed a mathematical theory of road-traffic control by means of traffic-lights. He defended his dissertation in 1968. His opponents at the defense were renowned scientists Igor Nikolaevich Kovalenko (1935 – 2019) and Alexander Dmitrievich Solovyev (1927 – 2001).

Beginning from 1968, on Mondays M.A.Fedotkin goes from Gorky to Moscow and back by train to be a listener at the Seminar in probability theory mathematical statistics, and stochastic processes, organized by academicians Andrei Nikolaevich Kolmogorov and Boris Vladimirovich

Gnedenko. He continues delevopment of his own mathematical methods and models of control for traffic flows. He gradually becomes one of top researchers in controlled queueing systems. All his research is done while in positions at NII PMK and at the Chair of Control Theory and Systems Dynamics of the Gorky State University. By year 1980 he writes his Doctoral dissertation. It was defended in 1984 in Moscow State University under the speciality 01.01.05 – Probability theory and mathematical statistics. The official opponents were academician V.S. Korolyuk, corresponding member of Academy S.V. Yablonsky and prof. G.P. Klimov.

As a newly-ranked Doctor of physical and mathematical sciences, he attains the opening of the Laboratory of methods of probability theory and mathematical statistics within NII PMK in 1985, and in 1986 he opens his own Chair of applied probability theory within the Department of Computational Mathematics and Cybernetics of the Gorky State University. Although Chairs of probability theory and mathematical statistics existed at several universities by that time, it was the first Chair in applied probability theory in the country. Its creation was voted for and supported by A. N. Kolmogorov, Yu. V. Prokhorov, B. V. Gnedenko, V. S. Korolyuk.

Figure 3: *M.A. Fedotkin read a lecture for MS students of Lobachevsky University*

For his creative growth, M.A. Fedotkin gives credit to the luck and happiness of meetings and conversations with many famous scientists, here are a few (in alphabetical order): T.A Azlarov, G.P. Basharin, Yu.K. Belyaev, L.N. Bolshev, A.A. Borovkov, N.P. Buslenko, B.V. Gnedenko, B.I. Grigelionis, V.M. Zolotarev, I.N. Kovalenko, A.N. Kolmogorov, V.S. Korolyuk, J.P. Kubilus, A.A. Lyapunov, N.N. Moiseev, N.N. Krasovsky, Yu.I. Neimark, B.N. Petrov, Yu.V. Prokhorov, Yu.A. Rozanov, T.A. Sarymsakov, B.A. Sevastyanov, A.G. Sigalov, S.H. Sirajdinov, A.V. Skorokhod, A.D. Solovyev, V.A. Statulevicius, I.A. Ushakov, A.N. Shiryaev, S.V. Yablonsky.

Apart of over 290 papers, he authored and co-authored text books and monographs on applied probability theory [2, 3, 4, 5, 6]. In the article [7] written by I.N. Kovalenko (2018), M.A. Fedotkin is called the leader of the Nizhni Novgorod mathematical school in the area of control of transportation flows.

2. His science

Scientific interests of M.A. Fedotkin lay in the following areas:

1) Dymanic systems for control of transportation flows.
2) Theory of controlled queueing systems with variable structure.
3) Adaptive stochastic control systems.

Figure 4: *Books written by M.A. Fedotkin*

4) Marked point processes and reliability theory.
5) Theory of functionals of sample paths of stochastic processes.
6) Cybernetic approach to construction, analysis, and optimization of probabilistic models of evolutionary experiments with control.

In his autobiographical book [1], M.A. gives extensive lists of references to his own works for each topic.

Below we'll review some of his contributions.

Application of Markov chains with incomes to transportation traffic control problems. In 1960 R.A. Howard published his book [8] (a Russian translation appeared soon in 1964) where a new branch of mathematics, dynamic programming, was applied to control problems for random processes. In his search for new approaches to transportation traffic control problems, M.A. Fedotkin proposed a mathematical model of a controlled intersection with a traffic-light in form of a multivariate stochastic process, and applied then Howard's policy iteration algorithm to generate optimal light-switching schemes. This model together with its numerical study was published in [9] and became a chapter in Candidate of sciences dissertation. Later, this research was continued by his Yu.I. Neimark and one Neimark's PhD students A.M. Preobrazhenskaya who also defended a dissertation on that topic in 1981.

Bartlett's traffic flow statistics. In the statistical theory of transportation flows M.A. Fedotkin also broke barriers and proposed a new viewpoint at the subject. He proposed a so-called 'non-local description' of a flow. In 1963 an English statistician M.S. Bartlett published a paper [10] with some sample data on inter-arrival times in vehicular flow near London and demonstrated that a classical Poisson model can't fit these data. Subsequent analysis of the data by D. Cox, P. Lewis, and others rejected several more models, e.g. a renewal process model. Fedotkin came to a conclusion that the reason for the failure was in desire to fit a traditional counting process model which observes each single arrival. He proposed to count arrivals only over large intervals of time. Since vehicles on a road move in groups with a slow vehicle in front, this idea seemed reasonable. Fedotkin splitted the Bartlett's data into 'groups of vehicles' and then he was able to fit a probability distribution for group size. In particular, the following probability distribution for the group size η worked:

$$\Pr(\{\eta = 1\}) = 1 - p, \qquad \Pr(\{\eta = k\}) = p(1-q)q^{k-2}, \qquad k = 2, 3, \dots \quad (0 < p, q < 1). \tag{1}$$

It was called the Bartlett's distribution by M.A. Fedotkin and his disciples. Further development of this approach resulted in several heuristic flow partitioning algorithms, and in a queueing model for vehicular group formation that explained, after 20 years, why the Bartlett distribution (1) was likely [3, Ch. 10] to explain road traffic. This branch of study was continued by M.A. Fedotkin's co-workers E.V. Kuvykina, L.N. Anisimova, M.A. Rachinskaya, E.V. Kudryavtsev.

Non-local description of a flow. From a classical point of view, a flow is just a stochastic sequence $0 \leqslant \tau_1 \leqslant \tau_2 \leqslant \dots$ of instants when new arrivals occur. Experience from having analysed

Bartlett's data led to the notion of a non-local description of a flow [11]. Basically, it can be defined as a marked point process

$$\{(\tau_i^{(\text{obs})}, \eta_i^{(\text{obs})}, \nu_i); i = 1, 2, \ldots\}$$

where $\tau_i^{(\text{obs})}$ is an observation moment, $\eta_i^{(\text{obs})}$ is the number of new arrivals during the time interval $(\tau_{i-1}^{(\text{obs})}, \tau_i^{(\text{obs})}]$, and $\nu_i \in M$ is a mark of all customers arriving during the interval, $i = 1, 2, \ldots$ (M denotes the set of possible marks). For example, to describe traffic flows we can include the traffic-light state into the marks. The flexibility of this new approach comes from the fact that, when the choice of the observational moments and marks is successful, we can build, analyze, and optimize quite sophisticated real-life systems not only in transportation traffic control, but also in mass production, information technologies, medicine etc.

Chung functionals. Reflecting of possible optimization problem statements in traffic control, M.A. Fedotkin came up with what he has called 'Chung functionals'. They were named after K.-L. Chung who extensively used taboo probabilities (transition probabilities with prohibited set) to study Markov chains. Let $\{X_n; n = 0, 1, \ldots\}$ be a denumerable Markov chain with the state-space S and $f(\cdot)\colon S \to \mathbb{R}$ a suitable function. Let S be partitioned into disjoint sets S_0 (admissible states), S_+ (target states), and S_- (forbidden stated). Define

$$\tau = \inf\{i\colon X_i \in S_+, S_j \notin S_-, j < i\}, \qquad \zeta = \sum_{i=0}^{\tau} f(X_i),$$
$$J(x; S_0, S_+, S_-) = \mathrm{E}(\zeta \mid \{X_0 = x, \tau < \infty\}).$$

Here the Chung functional $J(x; S_0, S_+, S_-)$ can be interpreted as the total income (or the total cost) of a Markovian random walk from the initial state $x \in S_0$ until exit from S_0 to S_+ without visits to the prohibited set S_- (think of the problem of unloading a crossroads without making even larger jams). In his paper [12] in the famous *Doklady AN SSSR*, recommended for publication by academician A.N. Kolmogorov, M.A. Fedotkin constructed an example where an infinite system of linear equations for the quantities $\{J(x; S_0, S_+, S_-)\colon x \in S_0\}$ might have several solutions, only one of them solved the original probabilistic model (before that, everybody believed such a system should have a unique solution).

This sort of optimization problems was applied to transportation traffic control by N.M. Golysheva and to priority queuing systems by A.V. Zorine.

Systems with varying structure and cybernetic approach Different particular models of qeueing situation with conflicting flows and algorithmic control, e.g. in road traffic control at intersections with complex crossing geometry, airtraffic control over takeoffs and landings of aircrafts, microwelding machines control for microchip production lines, led M.A. Fedotkin to invention of a unified framework for building adecvate queueing models, which are relatively feasible for analytical study and optimization. He called this framework a 'Theory of descrete systems with varying structure of service of quasi-regenerative flows' (this was the title of his doctoral dissertation). This framework assumed a non-local (integral) description of the source data, different operation modes of the server and the possibility of structural changes in at least one of the elements of a queueing system. Also, he advocated addition of new obligatory blocks to a typical queueing system, such as 'saturation flows', 'service algorithm' (explicitly spelled out as some mathematical entity, e.g. a graph), queuing discipline as a mathematical relation which specifies the actual amount of serviced customers as a function of the numbers in the queue, new arrivals, and saturation flows. This stage of development can be found in [13, 14].

Later he embedded this framework into even more general contept of an abstract control system — the term was introduces by pioneers of Soviet cybernetics Aleksei Andreevich Lyapunov and Sergey Vsevolodovich Yablonsky [15]. According to them, any abstract control system consists of only six functional elements: input and output poles, external and internal memories, information processing units for each memory. The link between the two approaches became clear after conversations with A.A. Lyapunov during scientific events, and discussion of M.A.'s dissertation with S.V. Yablonsky, an official opponent. Fedotkin added a (possibly random) external environment and demonstrated that this approach can solve not only queueing problems, but also management problems in hospital administration [6, 16, 17]. Moreover, this approach allows to solve a hard problem of studying output flows from controlled queueing systems.

This area of research is the richest with respect to the number of produced models and disciples and followers. O.A.Vaganov, E.V. Kuvykina, N.V.Litvak, A.A. Vysotsky, A.N. Kudelin, A.V. Zorine, E.V. Proidakova, A.M. Fedotkin, M.A. Rachinskaya, E.V. Kudryavtsev.

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