Pioneers in Computer Science: Andrey Kolmogorov

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1. Introduction

The modern computer science, rapidly developed in 20th and 21st century, is closely related with mathematical theories and inventions. The basic arithmetic calculations were used already in ancient computing tools such as abacus, Antikythera mechanism, and astronomical clocks [Sha95]. The binary logic concepts and Boolean algebra developed in 18th century are still used in modern computers and algorithms. The mathematical symbols, calculation algorithms and logic implemented in punched cards in 19th century are still used in modern programming languages [Sha95]. The Turing machine concept and Shannon’s information theory and symbolic analysis, which could be admitted as the early start of cybernetics and artificial intelligence, are developed further by many mathematicians and scientists. One of the greatest and known mathematicians of 20th century is Andrey Kolmogorov [Vit07].

2. Andrey Kolmogorov

Andrey Kolmogorov is known as the founder of modern probability theory. He got a great results and published many fundamental scientific researches in: topology, geometry, mathematical logic and classical mechanics, the theory of trigonometric
series, measure theory, set theory, the theory of integration, constructive logic (intuitionism), approximation theory, the theory of random processes, information theory, mathematical statistics, turbulence theory, celestial mechanics, dynamical systems, automata theory, theory of algorithms, mathematical linguistics, differential equations, Hilbert's 13th problem, ballistics, and applications of mathematics to problems of biology, geology, the crystallization of metals, and in functional analysis [Gre69][Vit07]. His life, achievements and implication on mathematical and computer science disciplines are described in the next chapters.

3. Childhood and Youth

Andrey Kolmogorov was born in Tambov, Russia, on 25\textsuperscript{th} (12\textsuperscript{th} by an old calendar style) of April 1903. His mother, Maria Kolmogorova, the daughter of the leader of Uglich nobility, died in childbirth. His father, Nikolay Kataev, was an agronomist by education, belonged to party of Right Revolutionaries, and worked as the clerk – statistician [Vit07]. Andrey’s father was not participating in his upbringing and died in 1919 [Khi16]. Kolmogorov’s parents were not married in church, and based by the law of these ages, Andrey has got his surname by his only uncle and godfather, Stepan Kolmogorov [SKh06]. Andrey has grown in Yaroslavl with three sisters of his mother. One of the sisters, Vera Kolmogorova has taken the responsibility of his grows officially [Gre69].

Andrey Kolmogorov has grown in a progressive family. His aunts were involved in a printing of the forbidden revolutionary literature, and have organized a small school, where they touched children by using the most new, well-known and progressive methodologies at these times. [SKh06]. As Andrey Kolmogorov told himself: “The happiness of mathematical “finding” I have recognized early, at the age of five-six, by noticing the legitimacy in calculation:

\[ 1 = 1^2 \]

\[ 1 + 3 = 2^2 \]
1 + 3 + 5 = 3²
1 + 3 + 5 + 7 = 4², and so on [Khi16].”

At the age of seven, Andrey Kolmogorov moved from Yaroslavl to Moscow with his aunt, where he started his school in Repman’s private gymnasium [Gre69]. His mathematical talent has been considered by the teachers, and most of the time Andrey Kolmogorov has learned mathematics himself much ahead other students, which led him to the acceptance in two universities in 1920: the faculty of Physics and Mathematics at the Moscow University, and in parallel a faculty of the Chemistry and Technology at the D.I Mendeleev’s institute [Gre69][Khi16]. In parallel of the mathematical studies Andrey Kolmogorov has participated in seminar on Old Russian History, organized by Professor S.V. Bakhrushin [Gre69]. Andrey Kolmogorov was usually narrating to his students about his historical passion. When the seminar work has been presented by young Andrey Kolmogorov, S.V. Bakhrushin, by approving the results, has commented that the history results should be proved by several prove facts. Andrey Kolmogorov said later that he has chosen another science, where there were enough to prove the results by one prove only [Vit07]. During the long time the history manuscripts of Andrey Kolmogorov were disappeared. Later, when the manuscripts found recently, the Russian history academician V.L.Yanin said: “If the scientific work done by Andrey Kolmogorov were published right after it has been done, our historical knowledge would be much fuller, and which is more important, more accurate…The history science has lost the genius researcher, but the mathematic science has gained him [Khi16].”

4. Scientific Work

Since 1920 the relation of Andrey Kolmogorov with the Moscow University, later named the Moscow State University, started [Vit07]. Fascinated by the lectures of his teacher and mathematician Nikolay Luzin, Andrey Kolmogorov has joined the mathematicians’ students’ group named “Luzitania”, where he presented his first manuscript disproving the statement, done by his teacher Luzin during the lecture
[Khi16]. The report done by Andrey Kolmogorov was recognized by the teachers and other students as well as his mathematical talent.

In 1922 he achieved the first famous and independent result in trigonometric series, the existence of Fourier-Lebesgue series with arbitrarily slowly decreasing Fourier coefficients [Vit07]. Later on in 1924, on a 4th year in university, he has found his interest in probability theory [Khi16]. He continued his work with Luzin on series topics, but at the same time has started to learn the classical analysis, measure theory and mathematical logics [Khi16]. During 1922-1925 he worked as a teacher of mathematics and physics at school, and in 1925, after finishing the university studies, he applied for the postgraduate studies [Vit07].

Andrey Kolmogorov invented an operation for “embedding” one logical theory in another. He published his first work on intuition logic, “The principle of “tertium non datur”[Khi16][Kol25], where he proved that application of the law of the excluded middle in itself cannot lead to a contradiction [Vit07]. In 1929 he completed his postgraduate studies in Moscow University, and has owned already over twenty important research publications and papers, such as the law of large numbers, proved law of the iterated logarithm for sums of independent random variables [Vit07]. Most of these papers were known in global mathematic science [SKh06].

In 1929 Andrey Kolmogorov has met Pavel Aleksandrov, the professor of Moscow University. They became friends, and as Kolmogorov described:” For me these 53 years of close and indissoluble friendship were the reason why all my life was on the whole full of happiness, and the basis of that happiness was the unceasing thoughtfulness on the part of Pavel Aleksandrov [Vit07].” With the support of Pavel Aleksandrov and cooperation with another mathematician A.Y. Khinchin, Andrey Kolmogorov has taken the single available vacancy at the Institute of Mathematics and Mechanics of Moscow University, and later on became a professor of Moscow State University in 1931 [Khi16]. At the same time he has visited Germany, where he met colleagues around the globe: R. Courant – the discussion on limit theorems, H. Weyl – the discussion on intuitionistic logic, and E. Landau – the discussion on function theory [Vit07][Khi16].
His paper “Analytical methods in probability theory” became a famous definitive
formulation of the probability theory, as a linkage of intuitive meaning, theory of random processes, mathematical analysis, and classical mechanics and physics [Vit07]. Andrey Kolmogorov provided the axiomatization of the probability theory as well [SKh06]. The modern view of the probability theory has been proposed and used by him, and became a little book named “Foundations of the Calculus of Probabilities”, which has been published in German in 1933. This work has opened the new branch of mathematics, and has included the creation of theory of random processes, published by Kolmogorov two years earlier [Vit07].

In 1935 Andrey Kolmogorov has founded the Department of Probability Theory in the faculty of Mechanics and Mathematics at Moscow State University, and became a head of this department [Khi16]. He was involved in almost all researches and was coordinating and mentoring almost all postgraduate students of his department, by involving them into the scientific works [Vit07]. Andrey Kolmogorov got a Doctoral Degree in 1935 [Khi16].

Together with Pavel Aleksandrov they bought a manor house at Komarovka, nearby Moscow, where they had a room for a large library, and which became a meeting place for mathematicians and students [Vit07]. As per Kolmogorov’s rule, four days of a seven days week from Friday to Tuesday, were spent in Komarovka. And one day has been reserved for the physical recreation, such as skiing, rowing, long trips on foot [Vit07].

During the period from 1935 – 1960 Andrey Kolmogorov together with his students has published scientific papers in many branches of science, such as: the work on approximation theory; “The basic concepts of probability theory” – first publication in Russian language; works on classical topology; the statistical theory of crystallization of metals – used in metallurgy; the works on mathematical methods - used for biological problems solving; works on the theory of shooting; findings in branching processes – the terminology used globally as a direct translation from Russian language; works on theoretical statistics; works on ergodic theory applicable to phenomena of the type of turbulence; solution of the 13th Hilbert’s problem [Vit07][Khi16]. During this period Andrey Kolmogorov was interested in cybernetics, first in his paper “On a new confirmation of Mendel's laws”, published in 1940, where he tried to apply the cybernetics on biology problems solving [Khi16]. A bit later Andrey Kolmogorov has
started his work on the algorithms, as a resulting interest driven from the probability theory, information theory, dynamic systems and mathematical logics [Vit07]. He has seen the great potential in Turing’s and Church’s works [Khi16].

Andrey Kolmogorov was interested in poetry as well, and in 1960 he published the work on statistical poetry analysis [Khi16]. The work has been further developed by his followers.

5. Interest in Cybernetics

During 1950th Andrey Kolmogorov together with his students made many researches in cybernetics that gave a basis for the later development in computer science. The computer science was just growing and establishing as a distinct academic discipline during 1950th -1960th [Sha95]. Most of the computer science related findings were done in physics and mathematics areas during these times. Andrey Kolmogorov said himself in his article “Automata and Life”: “I am not related to creating the basic ideas of modern cybernetics still. Norbert Wiener and Claude Shannon are. But the popularizing of these ideas in our country (Soviet Union) fell to my share.” [Khi16].

In 1950th the research done by Andrey Kolmogorov on dynamic systems topic led to a result of developing a general theory of Hamiltonian systems under small perturbations, which has practical adaptation in magnetic fields and plasma physics [Vit07]. This finding generated additional discussions and the development of KAM-theorem and KAM-theory, which has been named after Kolmogorov, Arnold and Moser, and gave conditions under which chaos is restricted in extent [Way08]. In 1956 Andrey Kolmogorov submitted a report “The theory of information transmission”, which included the mathematical representation of the results of information theory, and afterwards has been used same as by mathematicians and by the engineers [Khi16]. At that time Andrey Kolmogorov together with his students worked on theory of automata and the theory of algorithms. They created the Kolmogorov – Uspensky machine, operating on graph-structures [Vit07].
The combination of Andrey Kolmogorov’s researches, done in 1950\textsuperscript{th} in information theory, probability topic and the theory of algorithms, have driven him to a linkage between the universal descriptions of the finite objects, the use of recursion invariants, and the concepts of complexity of description, randomness and a priori probability. This research formed a result - the Algorithmic Information Theory, called as well - Kolmogorov complexity theory [Vit07].

Algorithmic information theory as the theory of individual objects shows the relation between computation, information and randomness. Andrey Kolmogorov defined the complexity of a string as the length of its shortest description on a universal Turing machine. The complexity was a measure of the calculation resources needed for the accurate determination of the object [Don12].

The ideas of Kolmogorov complexity has been developed independently and on several extensions by Gregory Chaitin in New York in 1965, and was related to proposals of R.Solomonoff in Cambridge, Massachusetts in 1960 [Vit07]. In 1973 Andrey Kolmogorov proposed the non-probabilistic approach to statistics and model selection, but in terms of Kolmogorov complexity, used as a term of Structural function [Vit07]. This idea has been developed further by his disciples. The invention in this complexity, done by Andrey Kolmogorov, is currently further developing and used in theory of machine learning, as a method, which allows synthesizing the machine learning algorithms [Don12].

6. Teacher and Founder

On top of the scientific researches Andrey Kolmogorov is known as a great teacher and founder of the practical laboratories and scientific departments, as well as an organizer of the mathematical schools and clubs. The mathematical evenings in Komarovka, organized by Andrey Kolmogorov together with Pavel Aleksandrov, was the first place where Kolmogorov tried to develop the mathematical creativity [SKh06]. He worked there alone, and together with scientists and his students [SKh06]. The mathematical
discussions in Komarovka were not limited to mathematics only. The guests were listening music, reading the poetry, and discussing on different problems [SKh06].

Andrey Kolmogorov taught mathematics and physics in an experimental boarding school in 1922-1925, was a lecturer in the Moscow State University [Khi16]. He was an organizer of mathematical competitions, paid attention on children with mathematical talent, and tried to organize and develop this talent. In 1963 Andrey Kolmogorov organized a specialized physics and mathematics boarding school as a branch of Moscow State University for gifted children coming from the province. The lecturers and the students of Moscow State University were teaching at that school [Khi16]. The new methodology proposed by Andrey Kolmogorov has been used in this school, and has been used as a base in mathematics and physics education reform proposed and later leaded by Andrey Kolmogorov, in 1960th [Gre69].

Together with other scientists Andrey Kolmogorov worked on school textbooks. The books like: “Algebra”, “Elements of the theory of functions and functional analysis” (1958), and books in geometry has been published by them [Khi16]. Andrey Kolmogorov headed the mathematics editorial board of the Publishing House of Foreign Literature and worked as editor of the mathematics section of the Great Soviet Encyclopedia, where he created for himself over 100 articles [Vit07][SKh06]. In 1970 he organized and published the mathematical journal for youth, “Kvant” [Khi16].

Andrey Kolmogorov got married with Anna Egorov, his classmate from Repman gymnasium, in 1942. They did not have common children, but Andrey Kolmogorov has trained Anna’s son Oleg, who was a student of the art high school, in math. As the result of these trainings, the foster-son of Andrey Kolmogorov became a mathematician [SKh06].

The results of educational reforms and modernization were evaluated ambiguously, as the reform has been counted as too complex [SKh06]. Nowadays the reform still continues to cause much controversy [Khi16].

Andrey Kolmogorov has founded the Department of Probability Theory in the faculty of Mechanics and Mathematics in Moscow State University in 1935. Many of the
inventions done by Andrey Kolmogorov have been published together with his students.

From 1938-1960 he worked as a head of Department of Probability Theory in Mathematical institution of V.A. Steklov in Academy of Science of Soviet Union [Khi16]. In 1939 he was elected as an Academician of the All-Union Academy of Sciences and as Academician–Secretary of the Physics-Mathematical Section [Vit07]. In 1951 Andrey Kolmogorov was appointed as a Director of the Mathematical Institute in Moscow State University. From 1954-1956 and from 1978 till his death he was heading the Faculty of Mathematics, and in 1954-1958 was a Dean at the Mechanics-Mathematical department of Moscow State University. During the spring 1958 Andrey Kolmogorov was teaching at the University in Paris [Vit07].

In 1960 Andrey Kolmogorov organized the Laboratory of Statistical Testing in Mechanics-Mathematical Department of Moscow State University, and in 1976 he organized and headed the new department of Statistical Mathematics of the faculty of Mechanics and Mathematics. In 1980 he headed the Department of Logic in Mechanic-Mathematical faculty of Moscow State University [Khi16].

7. Honours

Andrey Kolmogorov was honoured in Soviet Union by seven orders of Lenin, the Order of the October Revolution; he owned the title of Hero of Socialist Labour, and gained Lenin prizes and State prizes [Khi16]. He was acknowledged by honorary doctorates of Moscow, London, Paris, Berlin, Warsaw, Stockholm, Indian and other universities, and had honorary membership in: the Calcutta Mathematical Societies, the London Royal Statistical Society, the London Royal Society, the Royal Netherlands Academy of Sciences, the International Statistical Institute, the USA National Society, the Paris Academy of Sciences, the Polish Academy of Sciences, the Rumanian Academy of Sciences, the German Academy of Sciences Leopoldina, the American Academy of Sciences and Arts in Boston, and the American Meteorological Society [Vit07]. In 1963 Andrey Kolmogorov was awarded by the International Bolzano prize [Khi16].

In 1994 the Russian Academy of Science has established the premium, given to the leading mathematicians, named by Andrey Kolmogorov. Later on, in 2002 the
University of London has established the honour “The Kolmogorov Lecture and Medal”[Khi16].

8. Conclusion

In 1943, during the war time, all family of Andrey Kolmogorov was evacuated from Moscow to Kazan. He lived alone in Komarovka, and has started his diary with the words:” This diary is dedicated to my 80th birthday, with the wish to save enough sense at least to understand my own writings done in the age of 40, take them with sympathy, as well as with rigor [SKh06]”. He planned almost all of his life since 1943 till the end of his days, and was following this plan until his death [Vit07]. His scientific life calculated together gives 67 years. His work covers over 300 research papers and articles on different topics, as well as a great teaching experience and educational input [Khi16][SKh06]. He was always counting himself as mathematician, even was interested and was made his inventions in cybernetics, physics, biology and literature on top of mathematics. He died at the age of 84, on 20 October 1987, as a recognized scientist, great mathematician and a great person [Khi16].
References


