Obituary

Rūsiņš Mārtiņš Freivalds (1942–2016)

Rūsiņš Mārtiņš Freivalds, who suddenly passed away on January 4 aged 73 in Riga, Latvia, is the founder of ultrametric algorithms and celebrated for his fundamental contributions in many areas of theoretical computer science including complexity of computation, probabilistic algorithms, inductive inference of recursive functions and formal languages, and quantum computing.

Most if not all papers published by Freivalds are connected by his deep interest in the complexity of computation and his curiosity in what deep results and methods of classical mathematics could teach us about problems emerging in computer science. Many of the central themes he pursued during his scientific career are already present at the beginning of it; i.e., limiting computations of functions and functionals, and probabilistic machines versus deterministic and nondeterministic ones. The first of these research subjects triggered an impressive number of papers belonging to the field of inductive inference, which were and are highly influential.

Established by Jānis Bārzdiņš, the Latvian school of inductive inference (comprising in the early days Rūsiņš Freivald, Kārlis Podnieks, and Efim Kinber) rapidly reached a leading position in the world and stayed there for decades with the participation of many young scientists who graduated under the supervision of Bārzdiņš and/or Freivalds. One of the best-known results in this regard is the *halving algorithm* introduced by Bārzdiņš and Freivalds (1972) within the setting of function prediction and later adopted to on-line prediction by Angluin (1988) and Littlestone (1988), the latter one also suggested its name.

Further well-known results include a thorough study of the mind change complexity of various inductive inference algorithms including lower and upper bounds for the inductive inference of functions. And Freivalds would not have been

Freivalds if he did not introduce probabilistic inductive inference strategies in his FCT '79 paper. This paper had a deep impact, since it led to numerous investigations concerning the power of randomized inductive inference strategies including several papers published by R. Freivalds, E. Kinber, and R. Wiehagen (1984, 1988, 1989), and to mention a few more explictly: L. Pitt (1989), R.P. Daley (1988), R.P. Daley, L. Pitt, M. Velauthapillai, and T. Will (1991), R.P. Daley and B. Kalyanasundaram (1992), as well as A. Ambainis, K. Apsitis, R. Freivalds, and C.H. Smith (2001). Of course there are many more papers in this regard, e.g., by A. Sharma and S. Jain, by L. Meyer, and by C.H. Smith.

Taking into account that he was only allowed to travel outside the Soviet Union every other year this is even more remarkable. On the one hand, having these constraints it was highly non-trivial for him to stay in contact with the leading researchers outside the Soviet Union in general and with researchers outside the Comecon in particular. He used these opportunities to attend the *Mathematical Foundations of Computer Science* conferences in Poland and Czechoslovakia and the *Fundamentals of Computation Theory* conferences in Poland, Germany (GDR), Hungary and elsewhere. While many of the proceedings of these conferences were published in Springer's LNCS series, the FCT '79 proceedings appeared in a series published by Akademie-Verlag, hence their international visibility was severely restricted.

Another influential inductive inference paper is *On the Role of Procrastination in Machine Learning* by Freivalds and Smith (1993) in which constructive ordinals were introduced to measure the complexity of inductive inference.

In the nineties he extended his research interests to quantum computation. Without going into details, may it suffice here to say that the biggest impact to this field was the influence he had on his student Andris Ambainis by convincing him to make quantum computation his primary field of research.

Looking at the rôle of probability in the design of new efficient algorithms we see that it appears in different forms. Classical randomized algorithms use real numbers as their parameters. Quantum algorithms use complex numbers to describe amplitudes and then perform measurements to transform amplitudes into real numbers. At this point Freivalds realized that one could also use p-adic numbers as amplitudes and then to perform measurements to transform amplitudes into real numbers. This results in *ultrametric* algorithms which were invented by Freivalds in 2012. Two years later the paper *Active Learning of Recursive Functions by Ultrametric Algorithms* established a problem where ultrametric algorithms have advantages over nondeterministic ones.

Rūsiņš Mārtiņš Freivalds was born in Cesvaine on November 10, 1942 in Latvia, which was under German occupation at the time. In 1944 Latvia was re-occupied by the Soviet Union and became then the Latvian Soviet Socialist Republic. As a consequence, Freivalds grew up in the Soviet Union and succeeded

to enter the University of Latvia (at that time called "Pēteris Stučka Latvian State University"). There he graduated in 1965 at the Faculty of Physics and Mathematics. During the period of 1966 to 1970 he spent two years in Novosibirsk (Akademgorodok), one of the leading centers in computer science in the Soviet Union during this time. There he worked with Boris Trakhtenbrot, who was affiliated with both the Institute of Mathematics of the Siberian Branch of the Academy of Sciences of the USSR and Novosibirsk State University, and who became his supervisor. In 1972 he received his Dr. math (Candidate of Science in the former Soviet Union) for his thesis entitled *Completeness up to Coding for Systems of Multiple-Valued Functions*.

Back in Riga he continued his successful career and became head of laboratory at the Computing Center of the University of Latvia (1975–1985). During these years he achieved some of his best-known results in the area of probabilistic computations. The first appeared in 1975 and contains the very first theorem ever shown that establishes advantages of randomized algorithms over deterministic ones. Namely, he proved that randomized Turing machines can use less running time than deterministic ones to compute certain functions. The second is the nowadays famous matrix multiplication checker (also known as Freivalds' algorithm) which was published in 1977. In his invited ALT '97 lecture Manuel Blum mentioned this paper as the one which influenced him to introduce his paradigm of Self-Testing/Correcting of programs. And while it was well-known that deterministic and nondeterministic two-way finite automata can only recognize the regular languages, he showed in 1981 that probabilistic two-way finite automata may also recognize non-regular languages such as $\{a^n b^n \mid n \in \mathbb{N}\}$. These and many more results earned him the Doctor of Science (Dr. habil.math in those countries having a habilitation) from Moscow State University, former Soviet Union, in 1985.

Having received the Doctor of Science degree, Freivalds became eligible to be promoted to the rank of professor which he also received in 1985. From 1985 to 1990 he was professor and Deputy Director of the Computing Center, then leading researcher at the Institute of Mathematics and Computer Science, and from 1992 on he was Head of the Division of Discrete Mathematics at the Faculty of Physics and Mathematics of the University of Latvia. In addition, he held several visiting professor positions, at Hokkaido University, Sapporo, Kyoto University, Tsukuba University of Technology, Electrotechnical Laboratory, Tsukuba (all in Japan), Cornell University, USA, Malardalens University, Sweden, the National University of Singapore, at the University of Bonn, and Humboldt University, Berlin (both in Germany).

Many prizes and honors bear witness of his outstanding role in computer science and mathematics including the Grand Medal of the Latvian Academy of Sciences (2003), the Latvian Academy of Sciences and Joint Stock Company "Grindex" Prize (2003), the Latvian Academy of Sciences Eizens Arins prize for

a cycle of papers on *Effective Probable Algorithms* as well as Honorary Scientist of Latvian SSR (1986), and the Latvian YCL Prize for his work on *Theory of Inductive Inference* (1976). He was elected a Corresponding Member of the Latvian Academy of Sciences in 1992, a member of the Latvian Academy of Sciences (1992), and a member of the *Academia Europaea* in 2010.

Furthermore, it was very important for Freivalds to attract and to work with undergraduate students. He had a remarkable talent to find research questions for them and to stimulate them to solve these problems. His talent as a teacher maybe best reflected by the fact that in 2006 students voted him to be the "Teacher of the Year" for all of the natural sciences.

But this is not the complete story. Freivalds also actively participated in the introduction of a new school program on the "Foundations of Informatics and Computer Technology" in Latvia around 1985 (as I found out by searching the archives of academician A.P. Ershov). In this context I would like to mention that he published (together with his co-workers) 16 pedagogical texts and some more popular scientific papers.

The number of his scientific papers exceeds 200 publications of which at least 50 are difficult to find, since they appeared in Russian and under the name R.V. Freivald. For the curious among us, this was caused by the usage of his patronym, which was standard in the former Soviet Union.

On a more personal level I would like to finish this text by saying that Rūsiņš' eagerness to learn impressed me during all the years we worked together. When I was a postdoc in Riga (1987–1988), Rūsiņš requested me to teach him German, and I agreed. Given his tight schedule we met three times per week at 6:30 a.m. to study for one hour. So I remember him not only as brilliant, extremely nice and insightful friend and colleague, but also as an excellent pupil (as far as German is concerned).

The community will miss an extraordinary scientist, an inspiring teacher, and many of us a very good friend.

Thomas Zeugmann
February 2016.