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Obituary

Obituary for Professor Rudolf Emil Kalman

Professor Rudolf E. Kalman (photo by the courtesy of the National Academy of Engineering, USA)

Professor Rudolf E. Kalman, formerly graduate research professor and director of the Center for Mathematical System Theory at the University of Florida in Gainesville, Florida and the chair for Mathematical System Theory at the Swiss Federal Institute of Technology (ETH) in Zürich, Switzerland passed away peacefully in the morning of July 2, 2016, at his home in Gainesville, Florida. He was 86 years old.

Rudolf Kalman was born in Budapest, Hungary, on May 19, 1930. He emigrated to the United States and received his bachelor's (B.S.) and master's (M.S.) degrees in Electrical Engineering from the Massachusetts Institute of Technology in 1953 and 1954, respectively, and his doctoral degree (D. Sci.) from Columbia University in 1957. In 1958 through 1964, as a research mathematician at the Research Institute for Advanced Study (R.I.A.S.) in Baltimore, Maryland he produced a series of groundbreaking contributions that shaped the field of Mathematical System Theory and of Control Engineering. Chief amongst those was the "Kalman filter", a mathematical framework and an algorithm that enables navigation and control in virtually all modern-day apparatuses, from airplanes to satellites and from mobile phones to magnetic resonance imaging. In particular, in its early days, the Kalman filter proved pivotal in the success of the Apollo program that sent the first humans to the moon (Apollo 11, 1969). Fifty years since his seminal paper entitled "A new approach to linear filtering and prediction problems", the Kalman filter continues to find new applications in those fields as varied as weather forecasting, stock picking, econometrics, GPS, computer vision, autopilots, structural health monitoring, seismology and motor control.

After R.I.A.S., Rudolf Kalman became a professor at Stanford University (1964–1971). From 1971 to 1992 he was a graduate research professor and director of the Center for Mathematical System Theory at the University of Florida in Gainesville. Simultaneously, he held the chair for Mathematical System Theory at the ETH in Zürich from 1973 until his retirement in 1997. He received numerous awards, including the IEEE Medal of Honor (1974), the Rufus Oldenburger Medal (1976), the IEEE Centennial Medal (1984), the Kyoto Prize in High Technology from the Inamori Foundation, Japan (1985), the Steele Prize of the American Mathematical Society (1987), the Richard E. Bellman Control Heritage Award (1997), and Charles Stark Draper Prize for Engineering (2008). He was elected member of the National Academy of Sciences (USA), the National Academy of Engineering (USA), the American Academy of Arts and Sciences (USA), as well as member of numerous foreign Academies. He received many honorary doctorates and, in 2008, Rudolf Kalman received the National Medal of Science, the highest honor the United States gives for scientific achievement.

Rudolf Kalman's contributions to the systems and control field are fundamental in all aspects and their impacts are widespread. Particularly, in linear system theory, the transition from the classical transfer function approach to state space theory has led a fundamental paradigm shift in systems and control. As its outcome, there are such basic accomplishments as the Kalman filter, linear quadratic regulators, establishment of controllability and observability as basic system concepts as well as key solvability conditions for the Kalman filter and linear quadratic regulators, the separation principle between control and estimation, the inverse regulator problem, linear and nonlinear realization theory, design of sampled-data systems, canonical forms for dynamical systems, and introduction into system theory of methods in commutative algebra and algebraic geometry. These contributions laid the foundation of systems and control theory today and they have impacted modern technological and scientific developments across many disciplines. His research, ways of thinking and style have had a deep influence on countless engineers and scientists.

In research, Kalman had always emphasized the importance of a conceptual understanding of a problem, and a rigorous formulation of a right problem. The famous phrase "Hypotheses non fingo" (I do not frame hypotheses) from Newton's Principia was his favorite quote in conducting research. In quoting this phrase, he underlined the importance of a right problem formulation and also a *right* approach to avoid any ad hoc elements in the problem setting and its solutions.

He was also a purist in pursuing ideas to completion no matter how long or what effort that necessitated. His publications were gems, with no exception, in both elegance and scientific depth. The Center for Mathematical System Theory that he founded at the University of Florida was unique in its scope and reputation. His superb scholarship and magnetic personality was the heart and soul of the Center for over twenty years, attracting the most brilliant colleagues and contributors in Control, Dynamical

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Systems, as well as leading to many intriguing subjects in mathematics.

The seminars at the Center he presided over were superb opportunities to be exposed to a real example of how he thinks and how he poses research questions. During the seminars, he often raised questions that were deeply rooted in his fundamental approach toward science and technology. More than the face-to-face mentoring, such intellectual exchanges were precious occasions for his students to learn how one should approach a research problem.

Professor Kalman also gave several graduate courses. A favorite topic was algebraic system theory, with a focus on invariant theory and algebraic–geometric structures of canonical forms. The course was unique. He emphasized the motivation and the desired directions that he wanted to achieve, and developed the contents "on site". It was like a live process of showing how one should proceed in research. While there could be occasional changes of plans or deviations from the intended plan, the course was very clearly and concisely presented, and this highly impressed the course attendees.

We have lost an intellectual giant, not only in the field of systems and control, but also in many scientific disciplines that have relations with estimation, control and even beyond.

Professor Kalman is survived by his wife Constantina nee Stavrou, their two children Andrew and Elisabeth, eight grandchildren and his brother Otto.

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