

SPECIAL ISSUE IN MEMORY OF FRANTIŠEK MATUŠ

EDITORIAL BY NIHAT AY AND MILAN STUDENÝ

WITH MEMORIES FROM HIS COLLEAGUES AND CONTRIBUTORS

This issue of *Kybernetika*, divided into two parts, is dedicated to the memory of František “Fero” Matuš (1961 – 2018). The contributions were submitted by his friends, co-authors, followers and colleagues working in the areas close to his interests. Some of them were presented at the *Workshop in Memory of František Matuš*, held in Prague, August 19-23, 2019,¹ that attracted distinguished researchers from worldwide.

With the passing of František Matuš on May 17, 2018, we lost a man of many talents. He was gifted in mathematics and music as well as languages. František was born in 1961 in Poprad, Slovakia. He inherited his gift for music from his father, who was a university professor of music at the nearby University of Prešov. Nevertheless, František himself decided to study mathematics at Czech Technical University, Faculty of Nuclear Science and Physical Engineering in Prague.

He got his diploma in May 1984 and after a one-year break, filled by obligatory military service, started his PhD study in theoretical informatics at Czechoslovak Academy of Sciences, *Institute of Information Theory and Automation* (abbreviated ÚTIA in Czech), Prague. After graduation, Fero became a researcher there; in fact, most of his later scientific career was closely bound with this institute. He settled in Prague and married a Czech girl. His wife Jana was a Germanist and Bohemist, working in the Czech Language Institute of Czechoslovak Academy of Sciences. What Fero shared with his wife was the interest in foreign languages: he was able to speak actively in several European languages. In fact, Fero spent a part of his scientific career in Germany: he was awarded the Humboldt Research Fellowship and spent the period from September 1995 to March 1997 at the University of Bielefeld, Germany.

His research interests in mathematics were quite wide and he has achieved many important results. To appraise his contribution to mathematics he was awarded the Bernard Bolzano Honorary Medal for Merit in the Mathematical Sciences in 2019 (in memorial). Below we mention a few of the areas of his interest.

One of his research themes was the study of probabilistic *conditional independence structures*, in which context he applied his deep and wide knowledge of matroid theory. He wrote more than 15 journal papers on related topics, such as graphical models, axiomatization of functional dependency, relation to algebraic independence, and semi-

¹<http://simu0292.utia.cas.cz/pragstoch2019/mainFM.php>

graphoids. Another field in which František was involved was *probability theory*. He was interested in special random sequences and arrays and wrote at least 8 papers about them in the period 1996-2017. More specifically, these papers dealt with exchangeability characterization of two-block factor random sequences, generalized Markov chains, de Finetti theorems, and colorings of random sequences.

In *statistics*, he was specialized in the theory of exponential families and iterative procedures. His joint papers with Imre Csiszár, a prominent co-author of his, were devoted to information projections to exponential families, to variational closures of exponential families, to maximum likelihood estimates for exponential families and later to minimization of convex integral functionals. Following this line, František also became interested in *information geometry*, where the distance of probability distributions is measured by means of information-theoretical divergences based on relative entropy; for example, the maximization of information divergence from an exponential family was one of his favorite topics.

Fero's favorite research topic was the *entropy region*. Fero was particularly interested in (linear) inequalities valid for the entropy function. His well-cited result says that an infinite number of non-redundant inequalities of this type exist. These inequalities have application in cryptography, where they can improve bounds on information ratios in secret sharing schemes. Using these tools, Fero in cooperation with László Csirmaz succeeded in disproving the so-called *four-atom conjecture* formulated in the cryptographic community.

One of the themes to which he was returning throughout his career was the *matroid theory*. In fact, his last two journal papers were devoted to matroids: he succeeded in confirming a conjecture that every algebraic matroid is almost entropic, which means that its rank function can be approximated by entropy functions.

Besides writing papers, František was involved in the organizational side of his profession. He was a Deputy Chairman of the Board of the Institute of Information Theory and Automation and the Head of the Department of Decision-Making Theory of the Institute for several years. He also served as a referee for grant project proposals in mathematics.

Fero was also active in organizing scientific events like conferences and workshops. We have together organized several international meetings, ranging from mini-workshops to large conferences. František also liked lecturing: he gave lectures at the Faculty of Mathematics and Physics of Charles University in Prague. His favorite topics for lectures were exponential families and probabilistic methods in cryptography.

It was mentioned in the beginning of this text that music was another of Fero's lifelong loves. He mainly liked jazz but also used to attend concerts in classical music. He had musical education and played piano on a professional level: regularly, he used to play the piano after waking up in the morning. He also composed music and was an author of a few jazz compositions. There were some occasions at which he showed his music abilities to mathematicians. Some events have been held in places equipped with a piano, which gave Fero an opportunity to offer little piano productions in the evenings. We particularly remember his informal concerts during the IGAlA conference held in Liblice (Czech Republic) in 2016, and during a workshop on algebraic statistics held in Oberwolfach (Germany) in 2017. At both these occasions, the sound of the piano

attracted other participants' attention and they came to listen to his music production; in the end Fero was rewarded by long-lasting applause.

František Matúš left this world earlier than expected as a consequence of a serious disease. He will be missed not only by us, his colleagues in mathematics around the world, but, most of all, by his family. He was a caring husband, and a proud father to his son, Vladislav.

MEMORIES FROM CONTRIBUTORS AND FRIENDS OF FERÓ

We have asked some of the colleagues of Fero to share their memories to him with us.

Nihat Ay. I met Fero in 2002 at the first international conference on *Information Geometry and Its Applications*, which took place in Pescara, Italy. He was invited to present his work with Imre Csiszár, *Information Projections and MLE in Exponential Families Revisited*. We started to talk about this subject and its relations to my work. He was very interested in a problem that I had studied in my Ph.D. thesis, the maximisation of the Kullback-Leibler divergence from an exponential family, and I gave him my article on that. By the end of my own presentation, Fero had read my article and decided to work on that problem. That was the beginning of a long-term collaboration and deep friendship. He became a frequent visitor of my home institution, the Max Planck Institute for Mathematics in the Sciences, and interacted with a number of my group members. Over the years, he considerably advanced our knowledge on the above-mentioned problem, partly in collaboration with Johannes Rauh and myself. Fero and I co-organised two international conferences within the series *Information Geometry and Its Applications*, the conference that brought us together, and a number of workshops. Fero passed away too early. I will miss him as a collaborator and as a friend.

Aner Ben-Efraim. I met Fero for the first time as a master student, at the first workshop I attended. At that time, I was working on secret sharing and matroid representations, and, in particular, on multilinear representations of Dowling group geometries. I found his work “Matroid Representations by Partitions” fascinating, and he was kind enough to take interest in my work, and so we started communicating by email and exchanging ideas. After several failed attempts to find a partition representable non-multilinear Dowling group geometry, I sent him an email in which I conjectured that Dowling group geometries are partition representable if and only if they are multilinear, (naively) expecting him to give his opinion. But his response, only a couple of weeks later, contained the proof. We had planned to extend this result, but unfortunately due to his illness we did not find the time, and this research stopped prematurely. Therefore, I present his original proof in “A Note on Representing Dowling Geometries by Partitions”, in his memory.

I feel very fortunate to have known Fero and to have worked with him. He kindly invited me several times to visit him in Prague and to Mariánská (winter chalet of ÚTIA for small internal conferences). He was always very kind and hospitable. It was often quite a challenge for me to follow his shrewd logic and observations, but I felt privileged to work with him.

Lászlo Csirmaz. Fero frequently visited the Rényi Institute in Budapest, Hungary. Usually he stayed in one of the hotels nearby, in downtown. He loved music, especially jazz and opera, and knew all about the concerts and shows that were on at the time. He always made time to visit exhibitions and go to concerts. He bought last-minute tickets, which was no mean feat as the ticket sellers typically spoke Hungarian only, but he always succeeded.

On one occasion, he came at short notice, and all hotel rooms had been booked. Eventually the secretary who organized his accommodation found a private flat for rent. When he arrived, we paid a visit to the flat, which the owner showed around. This turned out to be quite difficult, as the landlord did not speak much Hungarian. Always helpful, Fero turned to him and said, ‘You can speak English’. The landlord shook his head. ‘German?’ ‘French?’ Fero offered. He shook his head again. ‘Then what language do you prefer?’ The landlord looked at Fero’s passport, then at Fero, and then his face lit up. ‘Italian!’ he said triumphantly.

The next moment Fero was speaking fluent Italian, expecting the landlord to answer his questions. But the landlord, defeated, just said, ‘I would rather stick with Hungarian’. For me, this episode clearly illustrated how truly well-rounded Fero was, from his trade in mathematics to music and languages.

Imre Csiszár My first closer contact with Fero happened in 1998 when both of us attended a meeting in Bielefeld, and he helped me to find a garage to fix my damaged car. As we share interest in geometric properties of information measures and exponential families, we soon started joint research. It lasted more than 15 years, with support of the Czech and Hungarian Academies, and resulted in 9 joint papers culminating in one about minimization of general entropy functionals subject to moment constraints (*Kybernetika* 48, 2012, 837-889).

One starting point of our collaboration was Fero’s finding of some erroneous assertions about exponential families in Čencov’s seminal monograph *Statistical Decision Rules and Optimal Inference*, Nauka, Moscow, 1972 (in Russian, English translation AMS 1982). As a remedy he suggested replacing the classical concept of a convex support (of probability measures on Euclidean spaces) by a new one we named a convex core. Using this idea we were able, among other things, to give a description of its variation distance closure in geometric terms for any exponential family, and a necessary and sufficient condition for the likelihood function to be bounded (implying existence of a generalized maximum likelihood estimate defined by us).

A pleasant by-product of our collaboration has been our becoming good friends. I have enjoyed working with Fero for his deep insights, and utmost care for mathematical precision and generality. His passing away too early has been a great loss not only for his family and colleagues at ÚTIA but also personally for me.

Oriol Farràs. Fero Matúš was my advisor during a research stay in ÚTIA in 2010. In that stay, I had the opportunity to know an excellent person who was a brilliant researcher. He left a legacy of clarity and honesty. After the Mariánská Winter School of 2017, we discussed the results included in this journal. He liked the idea of constructing secret sharing schemes for general matroid ports.

Tarik Kaced. I first got acquainted with Matúš through his papers that stood out from the usual easy-to-read, and sometimes shallow, works from the literature. It took me sometimes days (*and many nights*) to decipher his condensed and cryptic ideas, which, in hindsight, hinted that I found a hidden hard gem. Little did I know I would have the honour to have him as a Ph.D. thesis referee few years later. When I met Fero for the first time, I found a kind person whose pieces of advice bore striking similarities to his writing style: short, straightforward and extremely helpful – I admired him for that. He later invited me to a winter school in a setting that efficiently maximized interactions and gave participants a taste of the Czech lifestyle.

Following his works and papers has been rewarding, I always find his minimalist talks very accessible while his papers contains not-to-be-overlooked notes and remarks. Indeed, a short footnote question of his lead to a journal paper of mine. *I am sure more pearls are waiting to be discovered.* His fertile research style makes Fero someone to look up to, for I often learn something new each time I reexamine a piece of his work legacy.

Thomas Kahle. When I was a first year PhD student, I met Fero at a conference in Mikulov in Moravia. He invited me to visit his institute in Prague where I also gave my first talk abroad and learned about geocaching from him (long before smartphone GPS made this ubiquitous). On these occasions I remember being very impressed by the precision and efficiency of his research and writing. Fero had many unpublished manuscripts and ideas, just because for him these stories were unfinished. He had a laudable perfectionism. I am grateful to have met him and he has inspired me to strive to think through questions to the end.

G rard Letac. *Glimpses of Fero.* Through random meetings in Prague, Sardinia or Tunisia, it was always a great pleasure to meet this calm and modest man, who was actually a sharp mathematician. Among his wide interests I had been surprised to find the exponential families, a subject sometimes seen by statisticians with a bit of contempt, where everything seemed to have been said. However the deep results obtained in several papers with I. Csisz r force the admiration: one believes to master convex sets in finite dimensions, but a microscopic world exists if the convex set is neither closed nor open, and the study of the behavior of the exponential model when the observations are dangerously close to the border depends on these fine properties. On these topics like on many others, he had always an original point of view and was raising challenging problems. Fero, we miss you.

Rostislav Matveev. Much to my regret I have only met Fero three times in my life, twice when Fero was visiting Leipzig and another time when I have spent a week in Prague at Fero's invitation. These brief encounters, however, were aplenty for Fero, as a human being and as a mathematician, to leave a deep impression on me personally as well as on my mathematical research. Fero's humility and quiet demeanor served only to underscore his deep scientific insights while his generosity in scientific discussion witnessed his ample mind. I feel much indebted to Fero for the memories from the short time we spent discussing mathematics and other matters.

Milan Studený. I have met Fero first in the mid of the 1980's when we both entered our home Institute of Information Theory and Automation in Prague to start our doctoral studies; in fact, he came two years after me. We soon became good friends and also close co-workers. We shared several research interests but dominant theme of our cooperation was conditional independence. We more worked independently on this topic rather than we wrote all our papers together; however, we have written at least one journal paper on this topic as co-authors. That joint paper was the first one in a series of three papers in which Fero characterized all probabilistic conditional independence structures over four discrete random variables. That task was surprisingly demanding: it took him more than five years to reach the final verdict which was that there are 18478 such structures over four random variables.

In any case, Fero and I have strongly influenced and inspired each other. Fero's knowledge of the literature was admirable and I have quite often benefited from his advice. We have also been members of the same grant research team(s) for many years. Fero, unfortunately, passed away earlier than expected by his age. Nonetheless, he will always stay in my mind as an inspiring colleague and a good friend.

Raymond Yeung. In the 1990s, František (Fero) Matúš was active in probability theory research, in particular, in Bayesian networks. During that time Fero and Milan Studený were trying to characterize conditional independence structures for discrete random variables. They were successful in the 3 random variables case, but the 4 random variables case seemed much more difficult. In the mid-1990s, I proposed a geometrical framework for entropy inequalities and subsequently we worked with Zhen Zhang to discover a few so-called non-Shannon-type inequalities. I sent our preprints to Imre Csiszár. He thought our work had something to do with the problem on which Fero and Milan were working, and so, he sent the preprints to Fero. That's how Fero and I got to know each other.

In 1999, Fero organized together with Milan a workshop at the Fields Institute and invited me to participate. It was the first time we met each other. Fero was very excited that he was able to crack his conditional independence problem for 4 random variables with the help of a constrained non-Shannon-type inequality he devised. According to Fero, he got stuck with the problem for a long time because there was a certain conjecture of his that he was not able to confirm. He tried to use one of our non-Shannon-type inequalities but he was only able to prove what he had already known. Then he spent another year and a half to modify the constraints of our inequality so that the result could be used to confirm his conjecture!

In the subsequent years, Fero and I had been following each other's works. In 2007, Fero proved the existence of an infinite class of unconstrained non-Shannon-type inequalities. People were previously wondering whether non-Shannon-type inequalities are just some singularities in the entropy region. Fero's cornerstone result simply answered this question in the negative.

Fero will be remembered for his research legacy and as a good friend of many of us.

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editors of the special issue

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