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My Professional Life: Between Worlds

My background. My father was Austrian, my mother German. I was born in Zittau, Germany, in 1950. At the time, Zittau was part of the German Democratic Republic (GDR; East Germany). From birth, I was an Austrian in the GDR. I attended school in Zittau (ten-class general educational polytechnic secondary school, as it was called), completed high school (abitur) and a combined apprenticeship in electromechanics in Frankfurt an der Oder, and then started my studies in computer science at the Technical University of Dresden in 1970.

In those years, I began reading the scientific and technical literature. I found science fiction written, for instance, by the Polish author Stanisław Lem (1921–2006) extremely absorbing, creative, and inspiring. Not only was his technical fantasy based on scientific evidence, but also his illustration of utopian worlds influenced me very deeply. Quite a few years later, I also came to appreciate the descriptions of dystopian worlds by the U.S. science fiction writer Philip K. Dick (1928–82).

My studies in Dresden, East Germany. The computer did what you programmed it to do. I liked this, and consequently was inspired by my computer science studies!

The year I began university studies, 1970, was the second year that courses in what was then called information processing were being taught at the Technical University of Dresden. We learned a lot about mathematics, statistics, physics, formal languages and automata, computer languages (machine code, ALGOL 60 and 68), operating systems, systems theory and—last but not least—we had to study Russian and English. We also attended compulsory classes on Marxism and Leninism, as well as lectures on political systems theory. Millennia-old philosophical questions such as "What came first—matter or mind?" or "Can the world—in principle—be understood?" were addressed in these classes. I found these interesting but was averse to the politics of the time and its lopsided and pseudo-scientific, often erroneous arguments.

During my first year of these studies, I also attended lectures on cybernetics. We were taught to apply systems analysis approaches from cybernetics not only to technical and biological but also to societal systems (such as socialism in the GDR). These attempts did not yield the desired political conclusions. As a result, cybernetics was deleted from the computer science curriculum. Nevertheless, I was already, say, infected by the ideas behind cybernetic feedback circuits and the possibilities of unintended network consequences.

At the same time, I came in contact with a research group focused on pattern recognition. We programmed what were known as adaptive threshold units, which are closely related to artificial neural networks. Programming was done in ALGOL 60. This group also collaborated with the Institute of Pathology, Medical Academy of Dresden (now a part of the Technical University of Dresden). At the end of the third year of study, a three-month practical training period was prescribed by the curriculum. I completed this at the Institute of Pathology, focusing on a computational aspect of image

processing: calculating the ratios between cell protoplasm and nuclei in microscopic images of mouse tissues.

One day in 1973, we had the opportunity to witness an interesting and rare event in the autopsy room. A dead orangutan from the zoo in Dresden was brought in. The autopsy was performed in order to identify the cause of death. It was difficult to stay in the autopsy room: the odor was almost unbearable but made you aware of your senses. However, during the three months of my practical training, all elements of my subsequent professional life—namely computer science, research, and medicine—came together, forming my professional identity and paving the way for my future endeavors.

Unfortunately, despite my interest and enthusiasm, I was unable to continue working on such interdisciplinary research and medicine. As research, in the GDR, fell under increasingly stringent political controls, I was told I would be unable to pursue my research any longer. Being a citizen of Austria, I was not permitted to enter research institutions or even computer centers. Austria belonged to the Western hemisphere and the GDR to the socialist block. However, I was able to complete my studies and submit an MSc thesis in 1974 on a computer program for teaching Boolean logic.

In 1975, I finally decided to move to Vienna, which I was able to do legally.

At the Department of Medical Computer Sciences, University of Vienna Medical School, Austria. I arrived in Vienna and needed a job, ideally in research. I went to all of the universities, academies, and other research institutions in Vienna and its vicinity (there are many!) but did not find a suitable position. I then decided to join Siemens Austria as a programmer. We programmed in two-address machine code. This was a great job!

Later, in mid-1976, I received a phone call from Professor Georg Grabner (1923–2006), who remembered me from my interview when I first arrived in Vienna. He spoke to me about a job as a systems analyst at the Department of Medical Computer Sciences of the University of Vienna Medical School. Professor Grabner was not only the head of Medical Computer Sciences but also the head of the Second University Clinic for Gastroenterology and Hepatology. In essence, he was a clinician, but he was also a far-sighted, progressive, future-oriented individual who recognized the need for computer applications in clinical medicine.

I started to work on September 1, 1976 and was permitted not only to work as a systems analyst at the computer center of the Department of Medical Computer Sciences, but also to pursue research on this subject. My aim was to write a PhD thesis.

CADIAG—Computer-Assisted Diagnosis in Internal Medicine. The Department of Medical Computer Sciences, with its access to clinicians of the Second University Clinic of Gastroenterology and Hepatology, had started excellent work on computer-assisted diagnosis as early as 1968. Clinicians, together with mathematicians and statisticians, developed logical models for computer-assisted diagnosis in internal medicine, based on the seminal paper by Robert S. Ledley (1926–2012) and Lee B. Lusted (1922–94) on "Reasoning Foundations of Medical Diagnosis" published in *Science* in 1959.

After contemplating the then predominant two-valued logical approaches to medical data and clinical knowledge models, I developed a three-valued logic system (symptoms and diagnoses are present, absent, or not tested/unknown) based on Kleene's ternary logic. I found later that the ubiquitous unsharpness in the "boundaries" of linguistic medical terms (denoting concepts such as fever, leukopenia, or hypoxemia) could best be formally defined by fuzzy sets. Fuzzy logic would then be able to propagate the

calculated fuzzy logic values through a diagnostic inference network suggested and "established" by experts.

Together with clinicians from the Second University Clinic of Gastroenterology and Hepatology, but especially the rheumatology specialist Professor Gernot Kolarz, we started to develop medical knowledge bases for differential diagnosis in internal medicine: for clinical rheumatology with Professor Kolarz; hepatology with Professor Grabner; gall bladder and bile duct diseases, and pancreatic diseases with Professor Werner Scheithauer, and others. We collected an extensive body of data from actual patients, carried out accuracy studies, developed symptom and disease ontologies, programmed knowledge base consistency checking methods, and much more. These differential diagnostic consultation systems were named CADIAG. The process of development extended from 1976 to 2010. And maybe it has not ended yet!

My exposure to fuzzy set theory and fuzzy logic. Immediately after I discovered fuzzy set theory and logic in 1977, I started to develop fuzzy models for representing medical data and clinical knowledge. I redesigned the three-valued logic CADIAG system and extended it using fuzzy logic methods. Fuzzy sets, and later fuzzy logic, were developed by Professor Lotfi A. Zadeh (1921–2017), from the Computer Science Division, Department of Electrical Engineering and Computer Science, University of California (UC), Berkeley, U.S.A.

I presented my PhD thesis in computer science at the Vienna University of Technology in 1983, titled "A computer-assisted diagnostic system using fuzzy subsets". Since my arrival in Vienna, I had established close relationships with the informatics departments of the Vienna University of Technology, especially Professor Manfred Brockhaus, with whom we also started teaching medical informatics in Vienna. He was my PhD supervisor.

Teaching Medical Informatics. When I once visited the Vienna University of Technology to attend a class on database systems delivered by Professor Brockhaus, he invited me for a cup of coffee and proposed that we jointly develop a small curriculum for Applied Medical Informatics that would be available to his technical students. The aim was a collaborative project between the University of Vienna Medical School and the Vienna University of Technology. We included Professor Grabner and then prepared a comprehensive program consisting of topics related to medicine and medical informatics for informatics students. This was the beginning of medical informatics studies not only in Vienna, but also in all of Austria!

My post-doc at the Computer Science Division, Department of Electrical Engineering and Computer Science, University of California, Berkeley, U.S.A. In the course of my work on CADIAG-2 (or FuzzyCADIAG), the differential diagnostic consultation system for internal medicine applying fuzzy sets and fuzzy logic, I started to exchange letters with Professor Lotfi A. Zadeh, asking for technical literature and advice. As a result of our correspondence, he invited me to visit the Computer Science Division, Department of Electrical Engineering and Computer Science, UC Berkeley, U.S.A., as a post-doc, deepen my knowledge of fuzzy methods, and share my research with them. I actually had to apply twice for a fellowship from the Max Kade Foundation in New York, NY, U.S.A., awarded by the Austrian Academy of Sciences, in order to finance the trip and period of residence, and to be able to take my wife Christine with me.

My post-doc time at UC Berkeley (including extensions) lasted from 1984 to 1986. From the very beginning, we enjoyed the warmth and friendliness of Lotfi and his wife Fay.

Medical expert systems, clinical decision support, and running my own institute. Upon my return from Berkeley in 1986, I began a long phase of developing medical expert and knowledge-based systems for internal medicine, laboratory test interpretation, intensive care, and infection control. I intensified my contact with clinicians and the hospital administration, delivered classes on medical expert systems and fuzzy set theory, and supervised many MSc and PhD students, both from the Vienna University of Technology and the University of Vienna Medical School.

At the time, I was already the head of a Section (Institute) on Medical Expert and Knowledge-Based Systems at the Center for Medical Statistics, Informatics and Intelligent Systems of the Medical University of Vienna. Stimulated by developments in the U.S.A., I renamed my own profession clinical informatics, and myself a clinical informatician. This was to emphasize the direct patient-care-oriented work of our medical informatics research and development.

Editor-in-Chief of Artificial Intelligence in Medicine. My service as Editor-in-Chief extended from 2002 to the end of 2016: a period of 15 years. It was an extremely interesting but also time-consuming activity. We (the Editorial Office headed by Dipl.-Ing. Andrea Rappelsberger and myself) started with about 80 submissions per year in 2002. This number grew to approximately 350 by 2016.

CEO of Medexter Healthcare. Medexter Healthcare was founded in 2002. Medexter Healthcare is dedicated to the development and global marketing of innovative software systems for decision support with proven clinical usefulness. After its inception, Medexter has succeeded in establishing technical platforms and clinical decision support systems for a number of hospitals, commercial partners, and medical and teaching institutions.

Retirement and activities now. I retired from the Medical University of Vienna at the end of September 2015. However, I continued as Editor-in-Chief of the international journal Artificial Intelligence in Medicine until the end of 2016, still supervise MSc and PhD students, and now continue to work fulltime on software systems for clinical decision support with Medexter Healthcare.

Furthermore, I am very interested in the state and future impact of AI, especially in clinical medicine, in philosophical questions as to what computers can or cannot do usefully, safely, and ethically, and in processes of societal development in my immediate vicinity and also worldwide. I do hope these developments follow evolutionary paths towards humanistic, non-violent futures. Yes, several, possibly different ones! Why not?

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