Rajko Tomović - *Spiritus Movens* of the Biomedical Engineering and Technologies[1]

RAJKO TOMOVIĆ was born in Baja, Hungary, on in 1919. He graduated from the Department for Electro-Mechanical Engineering of the Technical University of Belgrade. He received his doctorate form the Academy of Sciences of Serbia in Belgrade in 1952.

Immediately after graduation of the University he started the unique productive carrier in developing and fine-tuning scientific and cultural integration of Balkans in both East and West. With his extraordinary language skills and excellent over-all education he was able to build a communication at the highest scientific level with the top scientist and engineers from the former Soviet Union, but also with the European and North American institutions and individuals.

Dr. Rajko Tomović started his professional career as a teaching assistant; yet, his spirit was too strong to keep him only in Academia. He was working for the Ministry for Electrical Power until 1950. He started working under the guidance of Prof. Dušan Mitrović in the field of system sciences. He was with the Institute for Nuclear Sciences "Vinča" from 1950 that after the second world was the institution dedicated by the state to be the leader. His main interest during the Vinča period was in design and use of analog computers, and he greatly contributed to the finalization of first analog and hybrid computers built in Vinča. The fast development of technology especially in the domain of electronics was one of the reasons for the Yugoslav government to develop other research institutions, among them the Institute "Mihajlo Pupin". Prof. Tomović moved to the Institute "Mihajlo Pupin" in 1960. While working at the Pupin Institute, he was instrumental for the early development of a scientifically productive Laboratory for Robotics. Prof. Rajko Tomović returned to the University of Belgrade where he became professor for Automatic Control in 1964. Rajko Tomović was officially retired from the Faculty of Electrical Engineering, yet he never stopped being engaged in various projects and student supervisions at both the Faculty of Electrical Engineering and in the Academy of Sciences and Arts of Serbia (SANU).

During the sixties Rajko Tomović spent periods in the U.S.A. as an visiting professor and visiting scientist at the leading U.S.A. universities contributing greatly to the development of new views and methods in robotics, biomedical engineering, and computer sciences. During this period he built extremely strong life-long lasting cooperation with scientists from the University of California, Los Angeles (UCLA), University of Southern California (USC), Los Angeles, and Ohio State University, Columbus, Ohio. His contacts and communications spread over Canada, the former Soviet Union, Poland, Czechoslovakia, Hungary, Bulgaria, France, Germany, Greece, Italy, Japan, China, and many other countries. It would be difficult to find a research institution involved in robotics, automatics, system sciences, biomedical engineering, and computer engineering and sciences that in some way was not connected to Rajko Tomović.

Based in his research results and contribution to the science he was elected to be a member of the Academy of Science and Arts (VANU), and after integration a member of Serbian Academy of Sciences and Arts (SANU). He was also elected to be an external member of the Slovenian

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Academy of Academy of Sciences and arts (SAZU). Rajko Tomović was decorated with the highest state medals and awards for his specific, yet also general contributions. He received the National 7th July Award, the highest award for the life accomplishment (AVNOJ Award), and many more recognitions for his research and societal work.

In parallel with his scientific work Rajko Tomović was very active and effective in his social and cultural activities. He was one of the founders of the Yugoslav Committee for Electronics, Telecommunication, Automatics and Nuclear Sciences (ETAN), Yugoslav Society for Computers, Yugoslav Society for Biomedical Engineering, Center for Multidisciplinary Studies of the University of Belgrade, Center for Strategic Social and Technical Planning in Novi Sad, and many other institutions.

Rajko Tomović was instrumental for the development of several activities within ETRAN. He was directly involved in the early work of the Sections for Biomedical Electronics, Automatic Control, Computers, Artificial Intelligence,

Rajko Tomović was always involved in the organization of scientific and engineering meetings, summer schools, and workshops that took place in Yugoslavia organized by ETRAN. These meetings were for a longtime a unique opportunity for East and West to meet. Yugoslavian meetings became places where scientists from the Soviet Union and other eastern countries met with their colleagues from North America and Europe. The series of 10 triennial international meetings "Advances in External Control of Humans Extremities", known as Dubrovnik meetings, resulted in 10 historic Proceedings that are used as the basic reference for the work in the rehabilitation of humans with an impact on movement.

An important constituent that characterized Rajko Tomović was his brilliant link to various high-level governmental and political organizations in the former Yugoslavia. This activity, recognized by the most important persons from the administration, was a key element in promoting the role of ETRAN in the organization of the research, education, participation in decision making, standardization, etc. Rajko Tomović was a good negotiator, and with his calm approach was able to attract and put together many individuals, and this led to many very important activities of ETRAN.

During the period 1955 to 1990 he succeeded to start and finalize several original, pioneering scientific and technological developments. Many of these activities received very strong attention around the world. His book about High-Speed Analog Computers (with Walter J. Karplus) published in 1962 introduced the electronic device systems to constitute a repetitive (analog) computer facility and was the first monography ever in the world. It was published in a short interval in French, English, and Russian languages. He is the author of the first monography dealing with sensitivity theory together with Dr. Miomir Vukobratović. Rajko Tomović is the author of the textbook Nonlinear Systems (1983) with Prof. Srđan Stanković and the book about Limitations of the Formal System Theory (1979) with Walter J. Karplus.

Rajko Tomović was a scientist with the greatest interest in large systems, specifically systems that are built by nature. He was constantly mining for the new knowledge in life sciences from the engineering point of vies, and trying to implement these findings in man machine made systems. One of the early, but best-known results was the multifunctional hand prosthesis, developed in collaboration with Prof. Miodrag Rakić from the Faculty of Electrical Engineering in Belgrade that led to the development of a series of rehabilitation assistive systems. This so-called Belgrade hand is posted in the Museum of Robotics in Boston, U.S.A.

He suggested the use of non-numerical techniques for the control of large complex systems. This method was an attempt to eliminate tedious and complex numerical procedures that essentially contradict the control in nature. The non-numerical control evolved into the logical control, and finally into the production rules based control. These two methods implement input-output mappings and connectivisms for controlling large complex, nonlinear systems. The production rule methods and input-output mappings gained from the machine learning and soft computing

techniques; thus became very efficient for the control of complex man-machine systems. In the eighties together with the colleagues from the Universities of Novi Sad and Belgrade, Rajko Tomović promoted the Belgrade/USC robot hand; at the time one of the most powerful robot grasping devices. In the early eighties Rajko Tomović lead the project for the Veterans Administration, New York, that resulted in the first intelligent powered self-contained transfemoral prosthesis. The prosthesis later evolved in the only intelligent prosthesis manufactured today by the German manufacturer "Otto Bock".

Rajko Tomović participated and contributed in many design and development projects including the first analog and digital computers for the Yugoslav army and defense systems. As a world-recognized expert and leader in the field, Rajko Tomović was frequently invited to chair, teach, instruct, consult, and contribute in other ways at various universities, international meetings, specialized workshop, major funding agencies, etc.

The best proof of the extraordinary abilities of Rajko Tomović is his students and collaborators. He taught several courses, mostly at the graduate level in the field of automatic control. He supervised many master and doctoral students. The students of Rajko Tomović became world known experts in their fields, and they are spread at almost every point of the planet. The Automatic Control of Belgrade is well recognized by the peers, and much of this recognition is linked to the name Tomović. In 1984, Dr. Norman Kaplan, Director of the National Science Foundation, Washington, D.C., gave an interesting, very valid depiction of the Rajko's personality; he said that Rajko is a renaissance scientist.

Dr. Tomović was the author of more than 150 scientific papers; most of those in well-recognized peer reviewed journals. Rajko Tomović was very frequently cited, and some of his works will be cited for a long time because they opened a completely new page in the development of control. Rajko Tomović (with Drs. Dejan B. Popović and Richard B. Stein) published the first monography in the world about nonanalytic methods for motor control (1995). Dr. Tomović wrote many invited chapters in the world encyclopedia and other edited books dealing with robotics, biomedical engineering, control of complex, large systems, and automatics.

Dr. Tomović was an active person in the political life of Yugoslavia, yet mostly working as an advisor and consultant. Throughout his life Dr. Tomović never compromised his cosmopolitan ideas on integration of things that are good and positive. There is no doubt that the last decade of his life and of the 20th century affected his life and activities, yet he succeeded to maintain his positive actions and non-compromised fight for the best.

This short biography of the Academician Professor Dr. Rajko Tomović would be incomplete if it would not include one totally different yet important dimension. Rajko was always able to find a right measure between his scientific and other activities that are characteristic only for good teachers and philanthropist. Rajko succeeded to prolong the day and night; thus, find the time for studying arts and philosophy. The piano and his collection of CDs were Rajko's runaway places; he was obsessed with good sounds of the classic music. The little pillow in front of the CD player and old gramophone, large collection of CDs and LP records, and headphones that can eliminate daily noise were inevitable parts of the living room furniture.

Reading of the mathematics and philosophy classics was the source of much inspiration that Rajko contributed to the world. It was always interesting to see and talk to Rajko in the morning after he just finished another chapter or article written by some pioneer in mathematics or computer science, physics, philosophy, neuroscience, or some other visionary discipline.

In parallel, Rajko was a passionate sportsman. Rajko was never cutting down on the sports, specifically rowing and tennis. Rajko had the second best result in rowing in his age group, and he constantly wanted to improve his performance while rowing with professionals that could be his grand children on the Sava River around his famous Ada Ciganlija.

Rajkos' love was tennis. It was intriguing to here Rajkos' comments about the required motor skills for this great game. Although he was in his eighties he was still trying to improve his shuts, he was spending time in practicing the service. Many times, Rajko was instructing much younger partners that they have to work on their fitness if they want to play with him. He was a born competitor; thus he was enjoying the match both when winning and loosing. His was able to use the sport spirit in most of his other activities.

The beginning of the year 2001 found Dr. Tomović ready for another scientific travel around United States of America. This trip included his last scheduled talk at MIT, Massachusetts and negotiation about the plausible collaboration, invited lecture at the UCLA, Los Angeles, experiments with colleagues, and many other important discussions. An unexpected disease stopped this intention and shut down a big light at the scientific sky of Balkans in 2001.

The authors of this text were students of Rajko Tomović, but in reality much more than that in the life of Rajko Tomović. He spent long hours with them, and tried to transfer the understanding that curiosity drives the good science, and that there is no time to waste. This parental, yet still professorial attitude likely helped them to at least partly continue his mission, and certainly spread his work to new generations.