Modelling – Another Approach to the Advancement of Diagnosis and Treatment

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ABSTRACT. Modelling has been in the focus of Medical and Biological Engineering from the beginning with the emphasis on simulation in order to analyse and interprete the behaviour of complex physiological systems, to test hypotheses about the internal system structure, and to reduce the number of (animal) experiments. Actually the first approach was the scientific approach with the aim to “reveal systemic functional properties of importance in understanding the underpinning of physiological function, and allow the effective analysis of physiological function under a variety of experimental or natural conditions” (Marmarelis, V.Z., 1986). During that first phase modelling in Biomedical Engineering has been driven by the application of engineering methodological knowledge and expertise to physiological systems, e.g. to neural networks, different controlled systems like the circulation, ventilation, and metabolism, to the sensory and the thermoregulatory system, and to pharmakokinetics, but also to single cells and even cellular components like the cell membrane, to special events like the membrane potential, to the opening-closing mechanism of membrane channels for ions and for the transmembraneous transport of other substances. However, the methodological limits became obvious very soon. “Biosystems problems, particular physiological ones, are natural fodder for systems science approaches, but one rapidly learns how limited our tools are, when confronted first-hand with real data” (DiStefano, J.J., 1988).

It became obvious very soon, however, that physiological systems are not only different from technical systems, but also that they need different methods for analysis and simulation. Parameterization of models in Biomedical Engineering, their verification and validation are much more difficult than in models of technical systems. Frequently non-linearities can not be neglected like in technical systems. Systems are rather of type MIMO (Multiple-Input-Multiple-Output) than SISO (Single-Input-Single-Output). The continuing challenge is to make “white-box” or at least “grey-box” models instead of “black-box” models. Models were increasingly described by the underlying physical and chemical reactions, sometimes down to the molecular (or ionic) level.

First concrete applications in medicine had been to the control of closed-loop systems, e.g. blood-pressure control during anaesthesia, artificial ventilation, glucose control by insulin injection, but also to the control of gait and hand-arm movements. The generation of excitations and their spreading across the cardiac muscle with subsequent contraction became one of the most favourite subjects, but also the simulation of electric current fields and magnetic fields using Finite Element Methods and other methods in order to understand the fundamental morphology of surface ECG and bioimpedance phenomena.

As a consequence of that more detailed understanding of the complexity of physiological systems and the availability of powerful computers and software it was found that modelling offers promising and new possibilities for medical purposes. Furthermore modelling was recognized as a solution for the problem how to organize appropriately huge amounts of multidimensional data about individual patients in order to meet the demands of personalized and evidence-based medicine. Modelling is now increasingly utilized to support diagnostic

and therapeutic processes with special regard of data interpretation, decision support, therapy control, healthcare management, and risk assessment. At present the focus is on image-based and model-guided surgery including the planning of reconstructive surgery, the interpretation of morphological properties in signals like the ECG taking into account individual images, and the model-based fusion of data acquired with different imaging modalities in combination with other multidimensional personalized data. Another interesting application is the use of advanced models in some kind of medical teaching, especially in remote or e-learning with the possibility for interactive training.

It is common understanding that models used in healthcare should start from a generalized type before becoming adjusted to an individual patient, and that the generalized model should be compatible with generalized models of interacting systems. The methodology for the general acceptability of models based on thorough evaluation by experts and standardization is still under discussion. The process may be similar to the introduction and acceptance by the concerned community of international technical standards.

Curriculum Vitae

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Helmut Hutten was born in Germany in 1936. He received his “Dipl. Ing.” degree from the now Technical University in Karlsruhe in 1961, and his “Dr.-Ing.” degree from the now Technical University Darmstadt in 1969. Between 1961 and 1964 he was working in a company before leaving to the Institute of Physiology at the University in Mainz. He completed his Habilitation with the venia legendi in “Biomedical Engineering and Biophysics” in 1972 and became a professor in the Medical Faculty of the University of Mainz. 1991 he was nominated the chair professor for Biomedical Engineering at the University of Technology in Graz and retired in 2004 as professor emeritus. At present he is still acvtive as external examiner for foreign universities and as consultant for companies.

He has served in many functions in different organizations. He was member of the AC of the German Society for Biomedical Engineering for more than 10 years, president from 1991 until 1993, and past-president from 1993 until 1995. From 1994 until 2000 he was member of the AC of IFMBE and chairing the Working Group for European Activities. In recognition of his merits he was elected as fellow of the IFMBE International Academy. From 2000 until 2003 he was member of the AC of IUPESM and chairing the Regional Development Committee. As consultant he was active in more than 100 projects for different governmental and non-governmental research funding organizations. From 1975 until 1996 he was Editor-in-Chief of the journal Medical Progress through Technology and reviewer for many national and international journals. He was organizer of different national and international conferences, primarily the 1st and 2nd European Medical and Biological Engineering Conference EMBEC in Vienna in 1999 and 2002, respectively. 2005 he was Honorary President of the EMBEC’05 in Prague. Since 1999 he is president of the non-profit organization EMBEC. He was member of the EAMBES Protem group and the first treasurer of EAMBES after its launching. At present he is the preliminary chair of the EAMBES fellows division. He was member in the German DKE standardizing committee for medical equipment for more than 10 years and head of the Notified Body 0636 until 2004. He and his students have received different awards. He was distinguished by a honorary doctor and by lifelong honorary membership in different organizations.

He has published more than 90 articles in reviewed journals and 20 book chapters. He is author or co-author of more than 280 published presentations in proceedings and more than 210 other publications. He is author or editor of several books. His scientific topics are medical electronics and instrumentation, pacemaker technology, blood flow measurement and microcirculation, analysis of physiological systems, computer-assisted modelling and computer-assisted therapy management with special regard to diabetes mellitus, dialysis and cardiomyopathy, biotelemetry and telemedicine, and health care technology assessment.