

Experiences in Teaching of Modeling and Simulation with Emphasize on Equation-based and Acausal Modeling Techniques.

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Abstract—This work introduces experiences of teaching modeling and simulation for graduate students in the field of biomedical engineering. We emphasize the acausal and object-oriented modeling technique and we have moved from teaching block-oriented tool MATLAB Simulink to acausal and object oriented Modelica language, which can express the structure of the system rather than a process of computation. However, block-oriented approach is allowed in Modelica language too and students have tendency to express the process of computation. Usage of the exemplar acausal domains and approach allows students to understand the modeled problems much deeper. The causality of the computation is derived automatically by the simulation tool.

I. INTRODUCTION

An important aspect of biomedical engineering graduate program is the ability to mathematically formalize the scientific knowledge in biomedicine and utilize such formalization – model – in engineering use cases like simulation, prediction, decision support etc.

There are several approaches, how a mathematical model can be expressed and implemented in an execution code which can be simulated using computers. One approach is to directly incorporate mathematical equations of the model as statements in some programming language code. This includes process of (1) definition of system, (2) decomposition of the system to subsystems, (3) modeling of the subsystems, (4) derivation of the computation causality and (5) implementation in programming language. Another approach is to separate the mathematical model from its simulator code and allow expressing the causality of the computation model in some higher level programming language and reduce the time of implementation (5). Such tools are usually denoted as block oriented languages. Examples are, e.g., industrial tool MATLAB Simulink, or domain specific languages to model physiology JSIM (NSR Physiome project introduced a JSIM Java based simulation system to support modeling in physiology and introduces a repository of several hundred of models [1]), CellML (IUPS Physiome project introduced XML based standard CellML and FieldML, tools and repository [2]), SBML (Systems Biology Markup Language (SBML) is used for modeling biological system at the level of biochemical reaction and regulatory network [3]).

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One of the first complex model of integrative physiology was model of circulatory system with its control regulation published by Guyton et al. [4]. This model was originally implemented in generic programming language FORTRAN and it gradually evolved to the current model HumMod published by Hester et al. [5]. It is not implemented in some programming language directly, they rather use an in-house XML-based domain specific language and tool to interpret and solve this model. Kofránek and Rusz published implementation of the Guyton's original model in MATLAB Simulink [6]. Due to the complexity of further integrative models, it becomes harder to maintain and keep the complex model updated and flexible using the mentioned modeling technology and tools. One of the reason is that the model express the process of computation. Therefore, Kofránek et al. chose acausal and object-oriented modeling language Modelica and implemented the current HumMod model in the standardized Modelica language [7]. Recently we have shown that the block oriented approach in modeling pulsatile cardiovascular system introduced by Fernandez de Canete et al.[8] may bring problems of further development and understandability. An acausal approach was shown by Kulhánek et al.[9].

Because no other modeling technology was suitable for the complex model Hummod, we started to teach the Modelica language within the classes of modeling and simulation which is executed within the last year of biomedical engineering curriculum with preliminary results promising good acceptance published by Ježek et al.[10]. Additionally, educational text in czech language was published by Kofránek et al.[11] to support the courses of biomedical engineering with focus on patient simulator and modeling methodology with an example of modeling cardiovascular system published originally by Meurs [12] and used in the ®Human Patient Simulator produced by CAE HealthCare¹. Such models and simulators are used further in teaching of students of medicine. This education methods and tools are shared within MEFANET network, Czech and Slovak Medical Faculties Network [13].

The students of biomedical engineering (of Czech Technical University in Prague, Czech Republic) are familiar with generic programming languages like C++, Java or interpreted Python etc. They are familiar with block-oriented modeling and simulation techniques and capabilities of MATLAB Simulink.

¹<http://www.caehealthcare.com/> accessed April 2015