Comparative study of tools for Computer Modeling and Simulation

Innovative methods of training of highly qualified specialists in engineering are used by the leading world universities. Realization of student-centered educational process demands using specialized software suits for instrumental modeling and simulation during the courses.

All the InMotion Partner Universities use different application suits in their own educational programs. These software applications are developed either by the Partner Universities (SPbPU — **Rand model designer**, NSTU - **ISMA**), or by large software developing organizations (MathWorks – **Matlab**, Dassault Systèmes – **Dymola**, Wolfram Research – **Wolfram system modeler**). Modeling and simulation environments are used by the Partner Universities, andby many world-leading universities as well.

Matlab should be highlighted as the most popular software for such purpose. Matlab and its toolboxes are intensively used by the Partner Universities (UL, NSTU, UTM, UTP, UniKL). That is because of huge support of mathematicians and programmers from all over the world, employed by MathWorks group, having offices in different countries and continents. However, note that the most popular software product can not always be used to effectively solve particular problems. For example, one may obtain ineffective solutions of inverse problems with Matlab (Alexandre Grebennikov, Fast Algorithms and MATLAB Software for Solution of the Dirichlet Boundary Value Problems for Elliptic Partial Differential Equations in Domains with Complicated Geometry. WSEAS Transactions on Mathematics J., Vol. ISS 4, 2008, pp.173-182) or even incorrect results numerically solving essentially stiff ODE systems (Novikov E.A., Shornikov Yu.V. Computer modeling and simulation of stiff hybrid systems: monograph. Novosibirsk: NSTU publishing house, 2012. - 451p.).

Discrete-continuous (hybrid) dynamical systems are usually studied by engineers. Hybrid systems (HS) are characterized by continuous modes which instantly change each other. In this case, the use of analytical methods of research is often impossible, and the simulation becomes the only universal way of studying event-continuous behavior. In most cases switching between modes is caused by one-sided events, i.e. the phase trajectory has discontinuities when the events occur. Modern computer modeling and simulation software (MATLAB/Stateflow, Rand Model Designer, AnyLogic and others) deal with HS, but they barely take into account one-sided events. That’s why, when training the specialists, one should focus both on the nature of engineer problems solved, and on capabilities and limitations of computer modeling and simulation instrumental tools. A specialist must be aware of a huge variety of visual modeling and simulation environments, be able to use the tools which are most appropriate to solve a particular problem, to prove their choice and assess the correctness of the results obtained.

A modern formalism, HS, can be effectively used by domain specialists via problem-oriented software applications for computer analysis. Examples of HS applications are automation, mechanics, chemical kinetics, electrical power systems, hydraulics and many others. Therefore each software application should be domain-oriented, and meet certain general requirements. The following **key requirements** can be singled out:

1) domain user-friendly interface with support of certain, usually standard, languages for specification of computer models;

2) advanced tools for editing graphical and/or textual program models with support of meaningful error diagnostics, and tools for effective analysis and transformation of the models for preparing the simulation;

3) modern library of numerical algorithms and tools for simulation, particularly, including a set of classical and original numerical methods;

4) visual graphical interpretation of the simulation results with the possibility to transform the data obtained.

These general requirements are, more or less, met by the chosen instrumental environments, used by the EU and the Partner Countries — the RF and Malaysia — under the InMotion project. A brief description of features of these software applications is given below.

Matlab (MathWorks, USA, http://www.mathworks.com/) uses Simulink environment with advanced graphical languages of block diagrams to analyze complex dynamical systems. A disadvantage is the redundancy of base blocks, many of which can be modeled as a composition of the others. An add-on, StateFlow, with graphical language of state diagrams (Harel statecharts) is used for studying discrete-continuous systems. Both graphical languages are interpreted in intermediate non-optimal code. The library of numerical methods is standard and is not tuned for specific problems from the mentioned class. The simulation results can not be edited.

Dymola (Dassault Systèmes, France, http://dymola.com/) uses an object-oriented multidomain language Modelica. The Modelica language is universal itself. Therefore, large component libraries were created to solve domain-specific problems: mechanical, electrical, electronic, hydraulic, thermal, power components, as well as control components and special process-oriented components.

The both component modeling approaches – with oriented and non-oriented connections - are implemented in Modelica. A new graphical model can be built as a set of equations and/or a composition of already existing elements. Thus, there is no need to describe basic model elements. A user only specifies variables and parameters, write equations and build a model from the existing blocks.

Extensive capabilities of the Modelica language allow a user to fully describe basic components and to build hierarchical models. However, it can be considered as a disadvantage because of the cumbersomeness of textual descriptions. Another disadvantage is related to possible user's difficulties with hierarchical decomposition during creating and editing models of complex systems.

Wolfram system modeler (Wolfram Research, USA, http://www.wolfram.com/system-modeler/) fully supports the Modelica language as well. There are numerous domain-specific libraries with detailed documentation and examples. There is a feature of integration with Wolfram Mathematica, which supports extended hybrid models and differential-algebraic equations.

Rand model designer (SPbPU, MVSTUDIUM Group, Russia, http://www.mvstudium.com/). Rand Model Designer implements object-oriented approach as well and contains the Modelica library. RMD generalizes the experience of Simulink and Modelica and strictly follows the UML standard, which is very important for educational purposes. From the analyzed modeling and simulation environments only RMD provides full support for models with variable structure. RMD requires Windows OS to run, which should be noted as a disadvantage.

ISMA (NSTU, Russia) is a domain-oriented multi-language instrumental environment for modeling and simulation of hybrid systems. A distinctive feature of ISMA is a set of syntax-oriented domain language tools. Due to the purposefully chosen API-architecture, various symbolic and graphical languages and means of their implementation are easily added to the system. Also without reprogramming the whole system, new numerical and event-detection methods can be added. The domain-oriented concept lets use the system to solve electrical power engineering, chemical kinetics, electromechanics, automation problems and so forth. For each engineering area, the special domain-oriented language, which is as close as possible to typical engineering description, in a graphical or in a textual way, is developed and implemented.

Another feature of ISMA is that the library contains well-known in the world modern numerical methods as well as the original methods, which take into account the stiffness, the dimensionality of problems and dynamics of the event-function during simulation of one-sided hybrid systems.

Moreover, unlike similar world-leading instrumental environments for computer modeling and simulation of problems from the mentioned class, a user can transform the simulation results in ISMA. For example, the wavelet transformation of large data sets, the catenation of graphic windows, the tracing of graphic data, etc.

Thus, the choice of modeling and simulation environment for educational purposes is related to the problems, which are faced by the students in the educational courses, and to the general idea of the educational program. As differential equations and state machines are almost standard for the input language of most of simulation tools, the theory of dynamical systems, basics of modeling and simulation should be taught using the language of mathematics, but any specific simulation tool language. For a basic mathematic modeling course, a teacher can use almost any mathematical package, performing ODE and DAE systems solving. In specialized courses, oriented on certain application area or on a detailed study of certain modeling approaches, a visual modeling and simulation environment, which supports necessary model types, is needed. In this case, the course developer should choose the most appropriate instrumental environment. However, it should be noted, that all the analyzed environments are capable of implementation of the tasks under the InMotion project.