Knowledge supported design and reuse of simulation models

Conference or Workshop Item

KNOWLEDGE SUPPORTED DESIGN AND REUSE OF SIMULATION MODELS

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Abstract
The paper deals with the description of implementation of new methodology being developed for the knowledge support of enriched simulation models used within design by simulation approach.
This design by simulation is used for the conceptual control design of mechatronic systems. The methodology is being developed within current EU FP5 project CLOCKWORK. The simulation models and process of their creation include a large amount of knowledge, which is related to the development and usage of dynamic simulation models. However, there are no or insufficient tools and support for storing, retrieving, reusing and sharing such knowledge.
Therefore there are being developed computational tools for enriching the traditional dynamic simulation models by the corresponding accompanying knowledge and reuse of such knowledge within team members. MATLAB/SIMULINK has been chosen as primary implementation platform as rapid prototyping, experimenting, expanding and interfacing is available and even comfortable. Prototypes of CLOCKWORK tools are already available and tested within CLOCKWORK consortium.

Introduction
Implementation of new methodology for the knowledge support of mechatronic design process used within design-by-simulation methodology is described. This design-by-simulation is used for the conceptual control design of mechatronic systems. The methodology is being developed within current FP5 project CLOCKWORK (1).
The design and usage of simulation models within engineering design is a very complex process. Engineering design is heavily based on previous experience and therefore it is essentially to build and maintain the archives of previous cases. It has been always done and it appears again for simulation models in some way.
The simulation models are associated with a large amount of knowledge, which is related to the development and usage of dynamic simulation models. However, there are no tools for storing, retrieving, reusing, sharing and communicating such knowledge. Therefore there are being developed computational tools for enriching the traditional dynamic simulation models by the corresponding accompanying knowledge.
Although MATLAB and SIMULINK are really ingenious tools, engineering tasks described above, i.e. developing complex simulation models consisting of many files (functions, data, libraries ..) is often difficult to maintain consistent.

Furthermore, it is not very easy or with limited capabilities to write notes about particular part of the software project or SIMULINK model and thus share knowledge across the cooperating team. Thus typical engineer working with MATLAB/SIMULINK develops very rapidly needed model, but makes no or insufficient documentation. When he must work with the project after few months it can be dificult to remind what he had been done

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and why. Transfer or sharing of the model or its part among colleagues or another department can nearly be night-mare, time and effort demanding procedure.

Tools described in this paper are trying to cover the gap described above for MATLAB/SIMULINK platform. They are aiming to help the user to enrich their projects and simulation models by additional pieces of knowledge, related to particular parts (entities) of the project.

The CLOCKWORK Scenario Tool supports enriching of MATLAB projects by additional information and helps with capturing of relations between particular MATLAB entities (files, SIMULINK models ...). The CLOCKWORK Enrich Tool supports work with SIMULINK model and provides means for enriching of SIMULINK model, its blocks and concepts (groups of entities) by additional pieces of information.

Simulation Modelling In Engineering Design

Design of mechatronic system, is a complex task. The key problem of the design of mechatronic product is the design of its dynamic functionality.

It is nowadays natural to use power of computers and simulation model of the mechatronic system or its subsystem to investigate and tune its properties and behaviour before the prototype is actually built. Modelling and simulation is the only known method for multidisciplinary system development synthesis. Also problem of many interactions within multidisciplinary system can be so coped. The importance of simulation is increasing with the usual non-linear properties of components of mechatronic systems.

The investigated design methodology is based on modelling and simulation. It is possible to distinguish the design through modelling and the design through simulation (3, 4). The scheme of design through simulation is described on the Fig. 1. In this approach the design starts with the assembled simulation model, formulated performance index of the required mechatronic system behaviour and the initial estimation of values of design parameters. The designer runs the simulation model with the values of design parameters and evaluates the performance index. Based on the values of performance index the designer controls the change of values of design parameters and repeats the simulation runs with their new values.

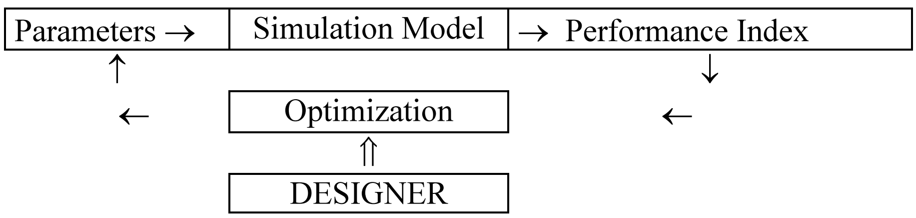

Fig. 1 Design through Simulation

Here the design procedure for the determination of the design parameters is their iterative modification within simulation loops. This design approach does not use directly the analytical form of the model (i.e. differential equations). Just the capability to simulate the behavior of the system suffices. Certainly the basic design procedure is the optimization, but also the adjustment of fulfillment of boundary conditions of system behavior by design parameter change is applicable design procedure. The design through simulation based on parameter optimization can be to great extent automated, for example the MOPO (multiple objective parameter optimization) approach (3).

Generally an engineering problem which is solved using modelling approach is solved within following problem cycle. At the beginning there is a problem in reality. The reality is first translated into physical (conceptual) model. This model includes ideal objects which are studied by engineering approaches. However, the process of translation is not unique, the reality is simplified and this process of suitable simplification is accompanied by raising many assumptions the fulfillment of which must be later checked, many decisions based on previous experience have to be done.

Based on the physical model the simulation model itself is created. In the past it has been done by formulating corresponding mathematical model in form of set of equations and rewriting them into computer program. Currently with improving software modelling packages the process of formulation of mathematical model is being replaced by assembly of simulation model from simulation elements (which are more or less close to the ideal objects from physical model. Good example is SIMPACK, software for MBS modelling). The clear perspective is merging the conceptual physical model and the simulation model itself. The set of differential equations is still used but hidden from simulation engineer.Then the simulation model is numerically solved. The results are examined from the point of view of fulfillment of assumptions which have been raised during formulation of conceptual physical model. Such examination leads to many iteration cycles within simulation model creation, i.e. it leads to modification of conceptual physical model, simulation model, its numerical solution. Once there is agreement between behavior of reality and simulation model, the results of simulation can be used for solution of the problem in reality.

Knowledge Associated With Simulation Model Design Process

The simulation models are created in an interactive subsequent iterative process. The creation of simulation model is done in a series of steps which will be called scenarios. A scenario consists of assembling a meaningful simulation model and providing an experiment with this model. An experiment means specifying input to the simulation model and evaluating the results (output) of the simulation. It seems that there is no simulation model alone but always a triple of some scenario (input, model, output), at least the last simulation model testing. A scenario could be also quite complex including several models and procedures, e.g. optimization for design by simulation according to Fig. 1. Engineer uses a lot of either formalized or informal, tacit knowledge associated with particular parts of simulation model design process.

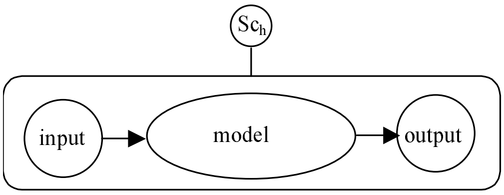

Fig. 2 Concept of simple scenario

Within process of using simulation models (Fig. 1) there is a quite complex sequence of scenarios. This structure is describing the solution process of the designer. It would be very valuable to capture it, save it, reuse it and/or learn from it. However, only a part of these scenarios is worth to be remembered and maybe saved (Fig. 3). But also the designer is agreeable to invest efforts into saving (and documenting) only a part of them. The rest including the structure of the solving process is unfortunately lost.

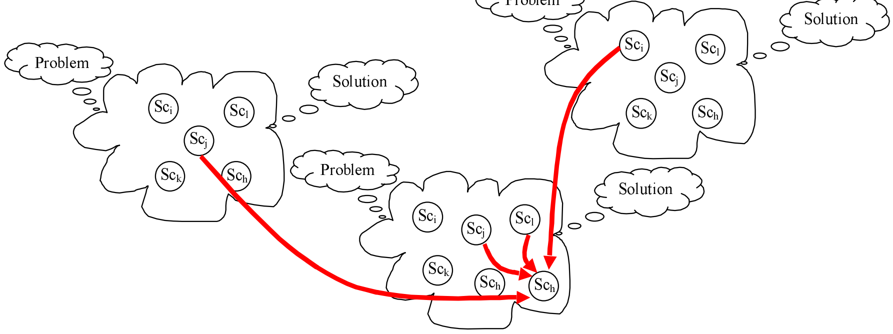

Fig. 3 Structure of scenarios and reuse of parts of previous simulation models

Knowledge Enriching Simulation Models

There are currently investigated ways of capturing knowledge associated with simulation cases. In order to support the capture of designer's knowledge intrinsic to the simulation models there have been developed two tools using the annotation technology (5). The tool called Clockwork Enrich Tool is designed for the annotation of the content of the simulation model itself. The simulation model is enriched at the level of their elements and contexts among these elements (Fig. 4):

1. Any element (block) in the simulation model (e.g. in Simulink) can be enriched (annotated) by textual information. Currently it is just pure textual information, later on this text can be more structured with formal descriptions like equations, figures, web addresses, keywords, ontology etc.
2. There can be introduced new elements called "context" elements into the simulation model (e.g. in Simulink). Such context element includes the links to several elements in the simulation model and describes the textual information related to the group of linked elements. Again currently it is just pure textual information, later on this text can be more structured with formal descriptions like equations, figures, web addresses, keywords, ontology etc.

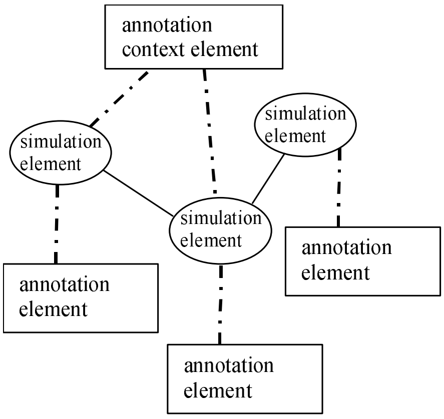

Fig. 3 Annotation concept for simulation models

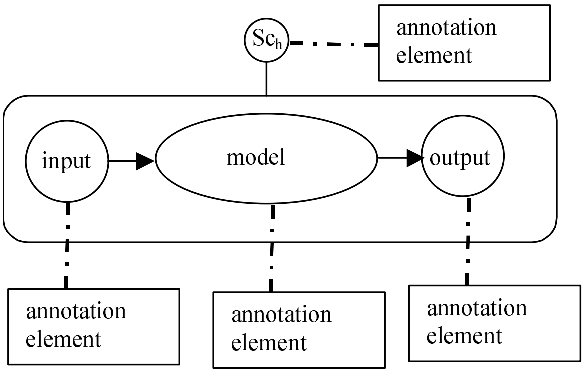

Fig. 4 Annotation concept for simulation scenarios

The other way is to enrich the simulation model at the level of complete models and their usage. The tool called Clockwork Scenario enables to create new elements called ‚scenario' connecting several computational scripts of MATLAB used within simulation runs (5). It directly corresponds to the scenario concept of Fig. 2. It consists of several files. It is usually a file describing the initial parameters and computation of other model parameters, a file with the particular simulation model and a file describing the evaluation of results of simulation run. Again the scenario elements include not only the links to the mentioned files but also the textual information related to the group of linked elements (Fig. 5). Currently it is just pure textual information, later on this text can be more structured with formal descriptions like equations, figures, web addresses, keywords, ontology etc.

Implementation

Discussed methodology has been implemented within MATLAB/SIMULINK environment with name CLOCKWORK Tools as MATLAB/SIMULINK has proved to be very powerful and efficient tool for Design-by-simulation methodology used in projects within our Mechatronic lab.

Furthermore, there are other nice features like object support, GUI development support and generally open architecture, which influenced the decision to use MATLAB/SIMULINK environment as a platform for methodology evaluation. MATLAB/SIMULINK also provides some basic tools for model annotations. These features are integrated with CLOCKWORK Tools. The intention of authors is to make use all the existing MATLAB and SIMULINK functions and capabilities for capturing of enriching information about the project or simulation model. For example, CLOCKWORK Tools cooperate with help texts in m-files or with SIMULINK model annotation, which is accessible through both SIMULINK menu and CLOCKWORK Enrich Tool. The tools support work of MATLAB or SIMULINK user and require minimum amount of additional knowledge, training or extensive additional effort during SIMULINK model development or MATLAB programming. Graphical interface with smart background is always available to help capture and classify enriching information.

The core of CLOCKWORK tools is concentrated into two main GUI windows, CLOCKWORK Enrich Tool for SIMULINK and CLOCKWORK Scenario Tool for MATLAB. Typical display configuration is shown on the figure Fig. 7.

CLOCKWORK Scenario Tool enables gathering and viewing enriching information about MATLAB projects and their entities, i.e. m-files, mdl-files, mat-files, and other files. It also enables to track, which entities (files) belong to the project. Any file can be eventually included into scenario. However, CLOCKWORK Scenario Tool GUI (see right side of Fig. 6) is primarily built to support information enriching of MATLAB/SIMULINK entities/files, which can be directly opened or edited with MATLAB means.

There is one unique entity, automatically included during scenario creation procedure called "Main Scenario Entity". It serves for global annotation of the scenario.

If the entity is m-file, it contains help text, which is displayed in MATLAB command window by command help `<m-file name>`. This in fact commented text (lines begin with `%` sign) in the beginning of m-file. As CLOCKWORK Scenario Tool maintains tight integration with MATLAB annotation and documentation means, help text of m-file is displayed in the GUI window part "MATLAB help of Entity (m-file)".

CLOCKWORK Enrich Tool supports enriching of SIMULINK simulation models during model creation, development and maintenance by providing means to capture, saved and later retrieve and modify annotations about entities described below. Annotated entities can be whole SIMULINK model, SIMULINK block, SIMULINK subsystem (which is in fact a newly created SIMULINK block) and Context, new entity introduced by CLOCKWORK Group, which enables to annotated several related blocks at once.

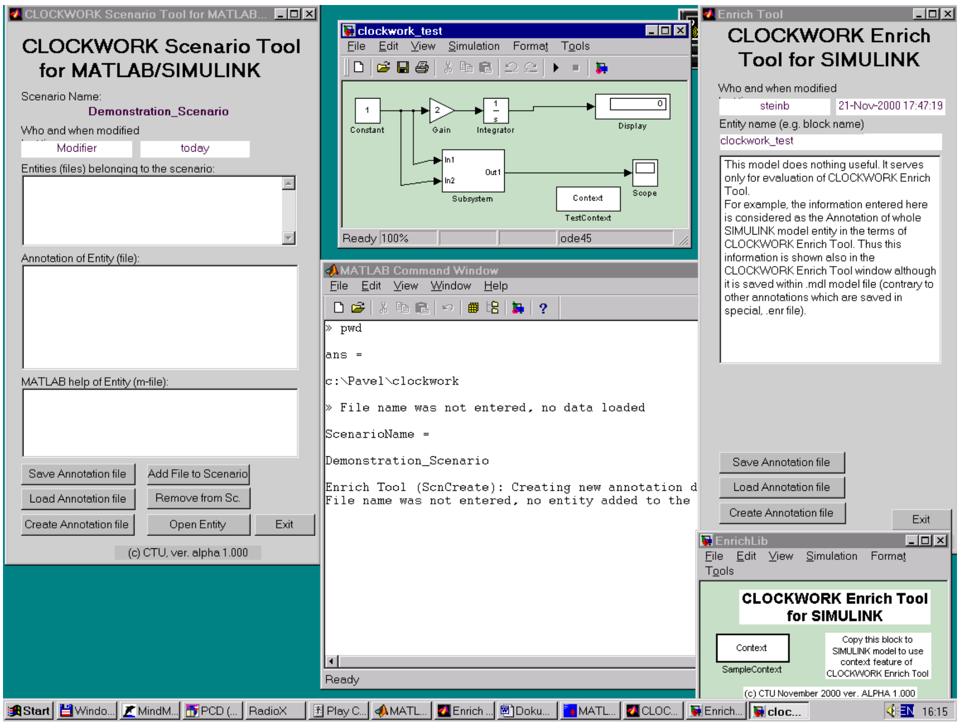

Fig. 5 Typical configuration of screen while using CLOCKWORK Tools

The GUI of the tool basically reacts to the motion of mouse pointer above the window. At that event system checks which SIMULINK block is chosen. If different block is selected than at the last check, the data from GUI fields are saved into `.enr` database and data belonging to the currently selected block are retrieved from the database and displayed for viewing and editing. Each entity in the CLOCKWORK Enrich Tool is also SIMULINK block in some sense. It is identified by the name of the block, which is always unique within one SIMULINK model. Although it is ensured by SIMULINK, it more useful to assign blocks own, model related and meaningful names.

The SIMULINK Model Global Annotation: Information entered here is considered as the Annotation of whole SIMULINK model entity in the terms of CLOCKWORK Enrich Tool. Thus comments about purpose of the SIMULINK model, its relation to projects, groups and so on are expected to be written here. The text entered here is available (for viewing or editing) both through SIMULINK menu (File/Model Properties) and through CLOCKWORK Enrich Tool (when no SIMULINK block is selected). It is saved also within `.mdl` model file.

Block Annotations: Block (e.g. multiplication, integrator, sum etc.) is basic wall stone of SIMULINK simulation models. However, very often also this small model unit has very important meaning and needs wider description-annotation (for example, the Constant block can mean a velocity of going car and thus range can be between 0 – 100 km per hour, the model does not consider negative contact force etc.). The subsystems are also blocks, although they contain often complicated structures and the related annotation is a comment of large part of SIMULATION model.

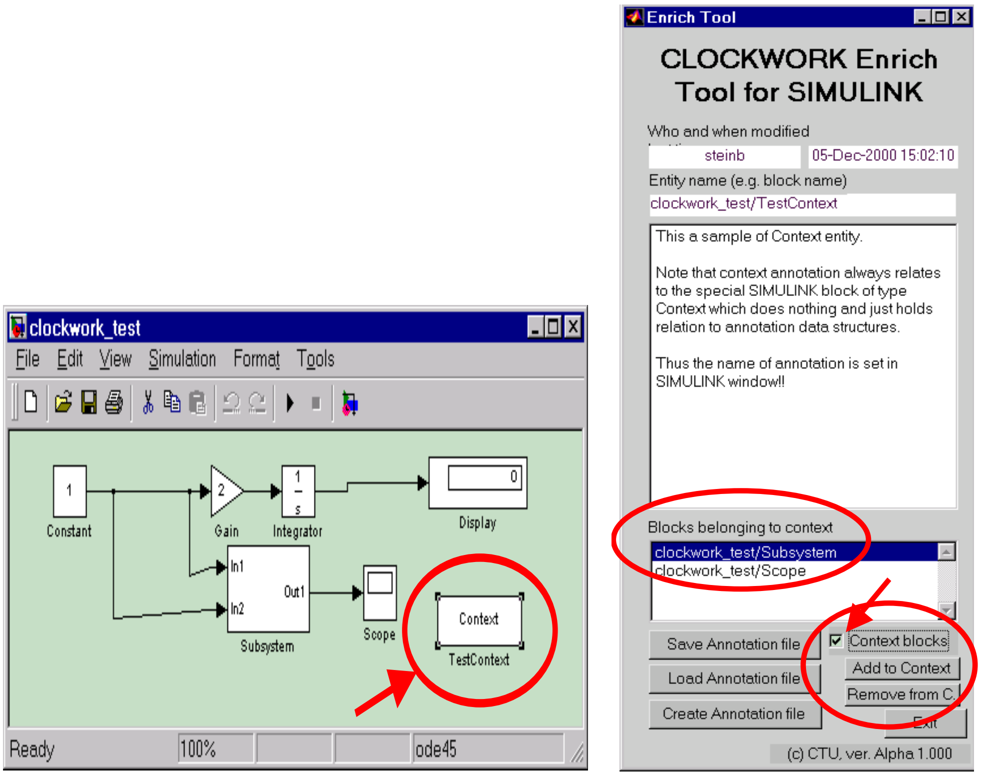

Figure 6 Context entity (block of type Context and EnrichTool window with Context enabled)

Context Annotation: Context entity provides means to annotate structure of blocks within simulation model. This structure of relationships is not necessarily visible or expressed by standard SIMULINK means. For example, annotation should stress that it is necessary to correctly set up parameters of several constant blocks and look-up tables. Every context entity is related to special (scenario) block to notify user that there is context entity among annotations and to improve integrity maintenance. This block does nothing during simulation of the SIMULINK model but holds the information about particular context. This block is available in the SIMULINK library `EnrichLib.mdl`. It must be copied into current SIMULINK model and renamed. When selected, CLOCKWORK Enrich Tool displays scenario annotation. If checkbox "Context blocks" is switched on, block names belonging to context (See Figure 7) are displayed together with additional control buttons. The behaviour of Enrich Tool changes in this case. Enrich Tool holds the annotation related to the context doesn't matter which SIMULINK block is selected. It enables user to add or remove blocks from particular context (buttons Add to Context, Remove from Context).

Typical Procedure of Clockwork Tools Use

CLOCKWORK Scenario Tool

1. User creates his MATLAB project (or its part).
2. User opens CLOCKWORK Scenario Tool GUI window by MATLAB command `ScnMain`.
3. User defines (Create Annotation Data button) new data structure or opens the previously saved one (Load Annotation Data button). At create procedure new scenario name must be entered, at load procedure correct scenario file name must be selected through standard GUI. The data are saved into file with suffix `.scn` into MATLAB working directory (in this alpha version).
4. User selects entity, which should be included into scenario. It is done by simple selection in the GUI part "Entities (files) belonging to the scenario" if the entity was already annotated or by mouse click by button "Add File to Scenario" if annotation for desired entity does not exist. If it is m-file, its help part is automatically displayed.
5. User enters or modifies annotation text (into GUI part "Annotation of Entity").
6. This loop is repeated until the project is finished or passed to partner and can be also done during MATLAB project development and tuning.

CLOCKWORK Enrich Tool

1. User creates and saves new (or opens old) SIMULINK model.
2. User opens CLOCKWORK Enrich Tool GUI window by MATLAB command `EnrichMain`.
3. User defines (Create Annotation Data button) new data structure or opens the previously saved one (Load Annotation Data button). The correct SIMULINK model must be active (last selected) at that moment. The data are saved into file with suffix `.enr` into MATLAB working directory (in this alpha version).
4. User selects particular block, which needs to be commented, switches into CLOCKWORK Enrich Tool window, this automatically displays annotation relevant to the block. If annotation still does not exist, it is created automatically.
5. The subsystems are handled in the same way as normal blocks. If no block is selected, Enrich Tool displays global annotation of the whole SIMULINK model, which is saved into both enrich data structure and SIMULINK `.mdl` model file.
6. User writes or edits annotation in the Enrich Tool GUI. The GUI displays the author and time of last modification of this annotation (see Figure).
7. Annotation of the context block is done in the same way as annotation of any other block. If blocks should be added or removed into/from the context, the checkbox "Context blocks" must be selected. Then additional control and display elements are displayed.
8. If context annotation is to be added, user must first copy Context Block from SIMULINK library `EnrichLib.mdl` into SIMULINK model and rename it.

Conclusions

The usage of these tools is intended for reuse of knowledge captured within previous simulation models and for support of communication among the members of the mechatronic design team. Thus design methodology „design by simulation“ being applied within design team is supported. The described methodology and corresponding tools are supporting the work with knowledge content of simulation models. The concept and tools are currently tested within trials of Clockwork project consortium. Further development is planned and foreseen to accommodate and improve it according test user experience, wishes, comments. In particular, the possibility to include equations, figures, addresses, ontologies into annotations is being investigated.

Acknowledgment

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