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MODEL-BASED DEVELOPMENT OF ENERGY-EFFICIENT AUTOMATION SYSTEMS

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ABSTRACT

We present an ongoing work towards a methodology for model-based engineering of energy-efficient automation systems. Energy consumption as an increasingly important decision criterion has to be included in the search for good architectural and design alternatives.

As a result of the work, new models of energy-efficient automation systems have to be developed. The methodology will have to show its contribution and industrial value by demonstrating the possible improvement for a real system design. New projects of equipment for energy saving will be developed and appropriate software will be created. As another result, we expect new methods of industrial energy consumption estimation.

The first task is a description method for energy consumption that can be simulated to evaluate and later optimize this non-functional property. An important candidate for this aim is the new UML [1] profile for Modelling and Analysis of Real-Time and Embedded systems (MARTE) [2], which might have to be extended or adapted for our project. The system simulation will be carried out after a transformation into a Petri Net [3] or MLDesigner functional block model [4].

A laboratory for testing and evaluating modelling and estimation quality of the work is being set up. A small lab plant will be realized based on the energy-controllable ATMEL microcontroller ATxmega128A1 and evaluation board. The first aim is to find the best possible control algorithm in terms of energy consumption minimum. The second aim is to examine the possibility of developing a microcontroller conception as a self-optimising system.

***Index Terms*—** Energy-efficiency, model, UML, MARTE, microcontroller

1. INTRODUCTION

Complex technical processes and automation systems which control these processes play a more and more important role. Nowadays, complex systems themselves can be efficiently controlled with the available control units. This is based on system design methods which can check the operation modes with the help of a model already before the realisation of an embedded system. In this case, the correct adoption of the desired functions into the classical design process is in the foreground.

In addition, such properties like timeliness and reliability are decisive in the embedded systems with which automation systems are controlled or realised. The other so-called non-functional property which is of great importance in the topical discussion about the resource-efficient management is the energy-efficiency of these systems. While some components in the industry like e.g. microcontroller are developed already with low power consumption, we should draw attention that an energy-efficient automation system as a whole includes a collaboration with the control system. There are currently no modelling and estimation procedures which could be applied already in early design phases for energy consumption observation. Besides, we should pay attention to the electronic/electrical system construction as well as the computer hardware and the executable algorithms.

2. ENERGY-EFFICIENT AUTOMATION SYSTEMS DESIGN METHOD DEVELOPMENT

In this project, modelling methods should be developed for discrete automation systems in such a way that the energy consumption beside other quality parameters can be modelled, estimated, and reduced. Energy consumption as an increasingly important decisive criterion has to be included in the search for good architectural and design alternatives to make an automation system as energy-efficient as possible.

For the existing models, simulation and analysis procedures have to be developed or adapted, so that alternatives can be valued and searched for the optimum with the help of heuristic procedures. The developed technologies should be realised in software tools.

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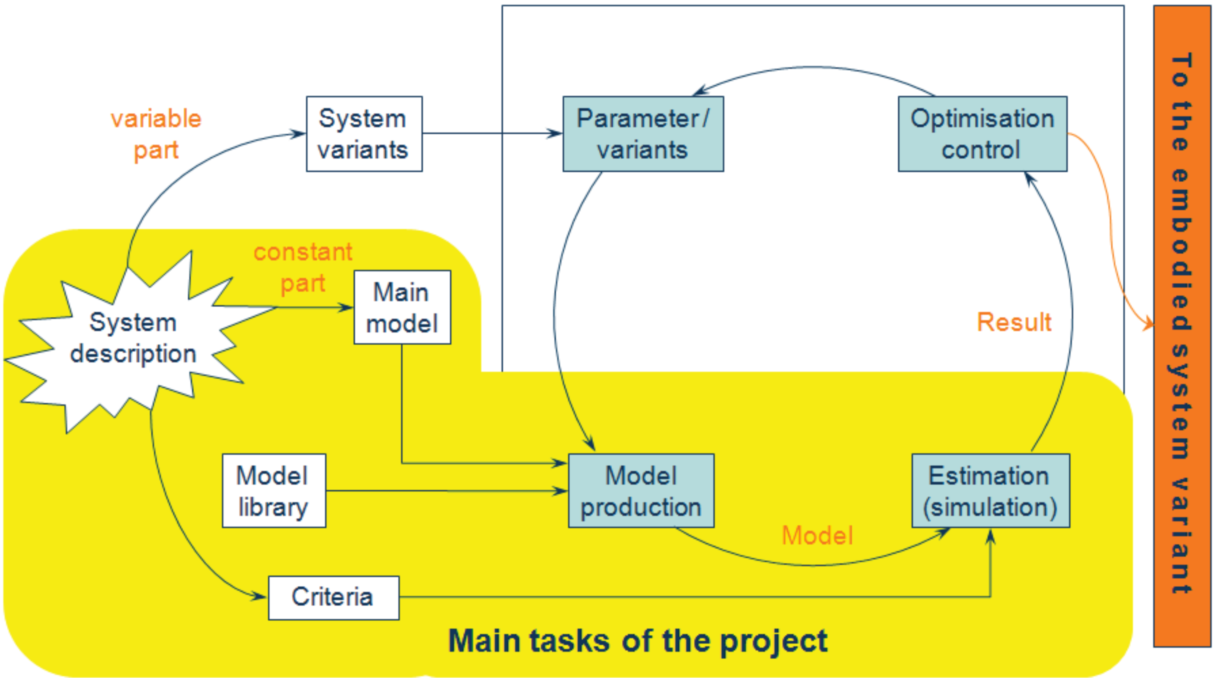

Fig. 1. Overview of the intended model-based design process

Fig. 1 presents a schematic overview of the intended procedure. The optimisation process is carried out iteratively (in the picture it is circularly shown) starting from a system description which consists of a main model describing of the firmly given elements, the system variations and the estimation criteria. A concrete model is generated from the main model with the help of a library of existing descriptions of subsystems or modules. In the last development stage, a parameter-choice procedure generates design variations automatically. The model is filled with the values of decision variables and afterwards the value of the criteria (optimization or cost function) is calculated by simulation.

The simulation estimates the model and gives a conclusion, whether and how good the parameterized solution meets the requirements. The system must be executable and can be simulated. In addition, the appropriate main models have to be used, e.g. the functional blocks used in our software tool (MLDesigner) or in Petri Nets (TimeNET) [5]. A good system interpretation is reached by a repeated definition of parameters and the system estimation, so that the finally "optimal" control parameters can be calculated. This gives the idea which system variation has to be realised.

The emphasised area in the lower part of Fig. 1 presets the most important working points of the project. The process shown in the figure is typical in this or in similar form for all model-based design processes. In this project, it is adapted for the consideration and optimisation of energy consumption. In addition, we elaborate the question in this first step how the system description of an automation system can be appropriately extended, so that the energy consumption is described and can be later calculated in the simulation procedure.

Lately, the technology state was more exactly analysed and searched in particular for suitable modelling means. The result can be summarised that this area receives topically increasing interest and such models are being researched, but still no generally approved standard exists. In the industrial sphere of the system and software engineering descriptions of the Unified Modelling Language (UML) are mostly used. However, it is not easy by the starting point of pure software directly to describe system properties suitably as well as there are no constructs for the non-functional properties estimation. Special profiles of the UML, e.g. MARTE Profile (Modelling and Analysis of Real-Time and Embedded Systems) as a successor of the UML SPT profile [6], are developed for some years to solve this problem. With its help non-functional properties like machine utilization, failures, temporal relations etc. can be described. The profile was developed especially for embedded systems and, hence, is suitable for our purposes better than UML alone.

Unfortunately, MARTE also contains no possibilities to model energy consumption. Our searches led us currently into the Tampere University of Technology in Finland which developed DPM (Dynamic Power Management) profile, a MARTE extension [7]. According to present state we would like to implement results from this research into our project and develop it if necessary.

Then the extended UML models contain the necessary information for the estimation, however, they are not useable directly. For the necessary simulation we will transform them in this project either into stochastic time-extended Petri Nets or functional block models, so that the behaviour and the properties are preserved [8]. Then the created models can be estimated with the software tools developed in our department MLDesigner or TimeNET. The results will provide information about the energy consumption of a system variation and accordingly a look at the consumption as a part of a more comprehensive estimation function.

Moreover, after the definition of appropriate models a model library of typical elements must be provided by embedded systems (see Fig. 1). For the remaining steps (parameter choice and optimisation) such usual heuristics like Simulated Annealing, Taboo Search or similar to natural procedures can be used. Besides, there are already extensions of TimeNET and MLDesigner in other projects which can be used in the project. For a rapid simulation of the transformed results the outcomes of some parallel running project, perhaps, can be used as well.

3. PROTOTYPE LAB CONSTRUCTION FOR THE RESULTS VALIDATION

The calculated values of system energy consumption must be checked by simulation to prove the functionality of the method in a real example construction. Besides, for the realistic values we need, for example, the energy consumption of a microcontroller in different operating modes. Therefore, the construction of a small test lab will be done simultaneously to the theoretical work.

After searching for an appropriate prototype a microcontroller development board was chosen, because its structure is simple enough for our purposes and it supports different operating modes for power-saving. The microcontroller ATxmega128A1 on the development board XPlain of the company Atmel was selected for this aim. It belongs to the XMEGA series which supports so-called picoPower technology.

4. FURTHER LINE OF DEVELOPMENT

The most important aims are

1. To find the best system design and control algorithm to minimise the energy consumption of the overall system

2. To use MARTE and DPM profiles for the appropriate models representation

3. Transformation into a model for simulation and estimation

4. Prototype realisation in software tools and its application into a real example (lab construction)

It is also possible to try to move the simulation into the running system to allow a self-optimizing system.

5. CONCLUSION

This paper presented an overview of the project towards a methodology for model-based engineering of energy-efficient automation systems. UML language with the MARTE profile and its extensions will be used for the modelling process. The models will be adopted into the functional blocks used in MLDesigner or in Petri Nets. For the field testing a microcontroller with many useful possibilities was chosen.

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