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Organization Committee of 19th Scientific Conference of Young Researchers of the Faculty of Electrical Engineering and Informatics, Technical University of Košice

Contact address:	Faculty of Electrical Engineering and Informatics Technical University of Košice Letná 9 042 00 Košice Slovak Republic

Final Proposal of Hybrid Systems Modelling, Analysis and Control Design Methodology within Distributed Control System

[1]*Dominik VOŠČEK (4^{th} year),*
Supervisor: [2]*Anna JADLOVSKÁ*

[1,2]Department of Cybernetics and Artificial Intelligence, FEEI TU of Košice, Slovak Republic

[1]dominik.voscek@tuke.sk, [2]anna.jadlovska@tuke.sk

***Abstract*—This paper presents final results during the last year of the studies in the field of modelling, analysis and control design of the cyber-physical systems as hybrid systems. The methodology for aforementioned tasks was proposed and then verified on either simulation or laboratory models, e.g. laboratory hydraulic model in the piece-wise affine mathematical representation. Another research activities were focused on the tasks within the international project "*Experiment ALICE on LHC in CERN : Study of strongly interacting matter at extreme energy densities* where already mentioned methodology can also be utilizied. At last, some research capacity was focused on broadening and modification of already existing Detector Control System communication and control architecture.**

***Keywords*—cyber-physical system, detector control system, hybrid system, linear temporal logic, methodology**

I. Introduction

Cyber-physical systems are defined as an integral part of emergency Industry 4.0 and are determined by synergy of computation platforms with physical processes. As far as CPS are concerned, many challenges arise, which are thoroughly described in [1] and [2]. Between one of these challenges belong modelling such a CPS within hybrid systems framework.

Hybrid automata (HA) is the natural framework for modelling hybrid systems [3]. HA provides determination of a tuple which incorporates system's continuous and discrete dynamics. Then after defining the HA tuple it is convinient to transform the hydrid system into another more suitable mathematical representation such as PWA or MLD. After this transformation, analysis and control design on such systems can be conducted. All of these steps are considered within methodology for modelling, analysis and control design of hybrid systems. Some of such systems are located at Department of *Cybernetics and Artificial Intelligence, FEEI, TUKE*, e.g. laboratory hydraulic system.

The main purpose of this paper is to give an overview of the proposed methodology for modelling, analysis and control design of hybrid systems and show its validation either on simulation or laboratory models as well as on applications within experiment ALICE CERN.

II. Previous Analysis and Achieved Results in Research Field

CPS are commonly described in the form of hybrid systems (HS) framework. This framework is based on finite state machines (FSM) framework augmented by continuous dynamics for some or each of the FSM discrete mdoes and therefore defining hybrid system framework as is. However not all of the FSM discrete modes have to have defined continuous dynamics, such as lift system [4]. For this kind of hybrid systems it is convinient to define some transitions and behaviour via linear temporal logic as it can be seen in Fig. 1, [5].

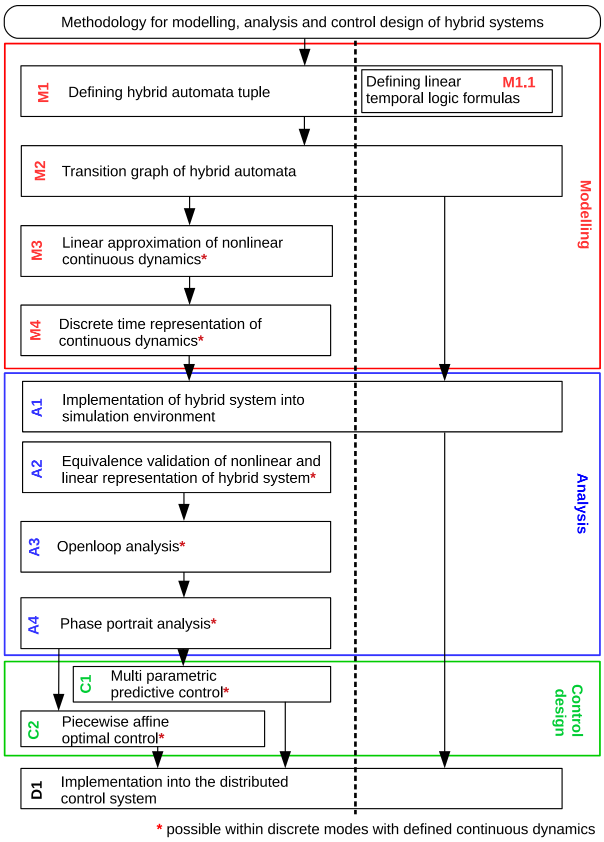

Fig. 1. Methodology for modelling, analysis and control design of hybrid systems

III. SOLVED TASKS AND RESULTS

Considering achieved results within the previous year, the process of modelling, analysis and control design was generalized and unified within the complex methodology for hybrid systems. This methodology can be utilizied either on the systems with all discrete modes containing continuous dynamics (left half of the Fig. 1) or on the systems with some discrete modes without defined continuous dynamics (right half of Fig. 1). The results from simulation hydraulics model were processend within publication *Modelling, Analysis and Control Dwsign of Hybrid Dynamical Systems* which is currently being under review. Then this methodology was validated on the laboratory hydraulics system with all the step from the left half of the Fig. 1. Results from the steps *A3 - Openloop analysis* are shown in Fig. 2.

As far as the project "*Experiment ALICE on LHC in CERN : Study of strongly interacting matter at extreme energy densities*", is concerned (http://alice-cern.fei.tuke.sk/), research activities were focused on the implementation and modification of existing software-hardware architecture based on replacing emulator electronics with the custom electronics modules from CERN such as PowerBoard, ReadoutUnit and others. This communication-control DCS architecture represents complex distributed CPS with defined all the challenges in [1] and [6].

Moreover, another research focus was on the simulation of the final *Detector Control System* load. This is particularly important as the whole new *Inner Tracking System* detector is not yet built. So for this to happen, the data generator software module, which satisfies all the CPS specifications, was implemented within SCADA software *WinCC OA* utilizing aforementioned methodology with some discrete modes without defined continuous dynamics. Linear temporal logic formulas were used during the designing and implementation phase and transition graph is depicted in Fig. 3.

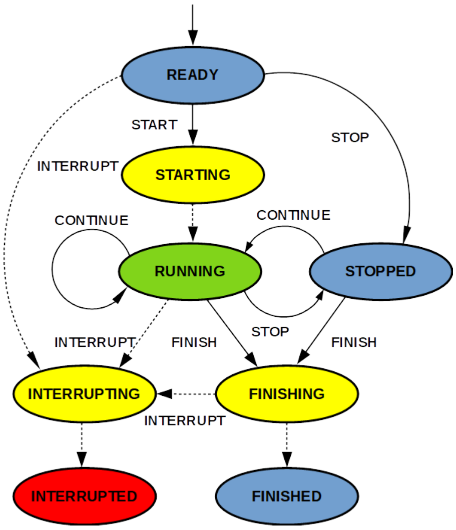

Fig. 3. Transition graph of data generator for testing load of DCS

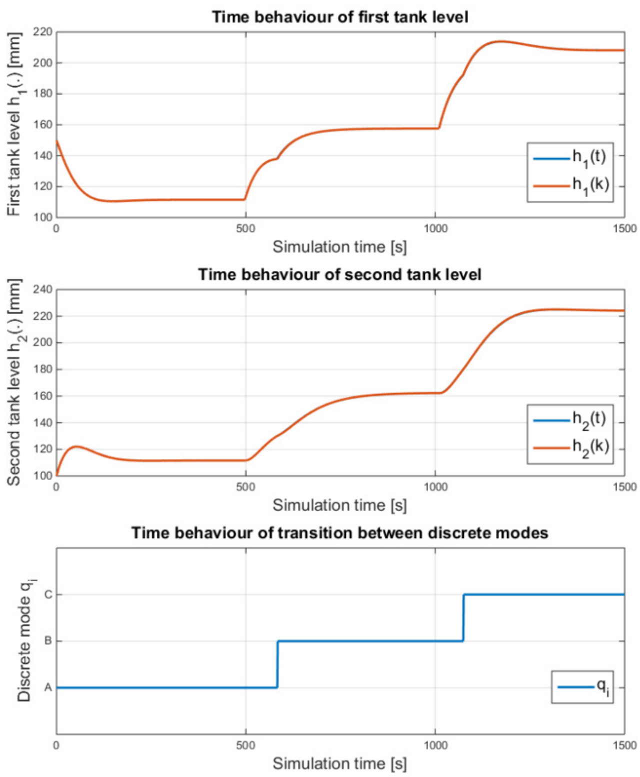

Fig. 2. Time behaviour of individual tank's height of laboratory hydraulic system

IV. FUTURE RESEARCH STEPS

This paper was written in order to summarize the research activities of the author during the previous year. The main contribution is in the proposed general methodology for modelling, analysis and control design of cyber-physical systems in the mathematical representation of hybrid systems.

This methodology was then validated on simulation as well as on laboratory models at *Center of Modern Control Techniques & Industrial Informatics* (CMCT&II) at *DCAI FEEI TU*.

Another contribution can be considered in the implementation of the proposed methodology on the research activities within project "*Experiment ALICE on LHC in CERN : Study of strongly interacting matter at extreme energy densities*", either on the load generator or communication-control architecture DCS.

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