

Modelling, analysis and control design of hybrid dynamical systems

Dominik Vošček, Anna Jádlovská, Dominik Grigľík*

This paper introduces a methodology for one of the challenges regarding cyber-physical systems, i.e. modelling and control design them as hybrid systems. The proposed methodology comprises modules with specific steps to accomplish the tasks. Specifically, the paper aims to utilize hybrid systems framework onto the chosen hydraulic hybrid system with complex dynamics to showcase different aspects of hybrid systems. The mathematical model was derived using hybrid automata framework and then transferred into the linear form either using Jacobi matrices or using linear approximations without Jacobi matrices. After that the system was validated and analyzed and the control design utilizing piecewise linear-quadratic regulator optimal control was proposed. Furthermore, parameters of control algorithms were tuned using particle swarm optimization algorithm. The whole logic, system dynamics and constraints are implemented within MATLAB/Simulink simulation environment using s -functions. The proposed methodology can be implemented on the various types of cyber-physical systems as far as they can be described as hybrid systems.

Keywords: cyber-physical system, hydraulic hybrid system, methodology, particle swarm optimization, piecewise affine systems, piecewise LQR optimal control

1 Introduction

Cyber-physical systems (CPS), defined as an integration of physical processes with computation platforms, are an integral part of the phenomenon Industry 4.0. One of their complexity challenges stated in [1, 2] can be formulated as to model and control CPS within hybrid systems framework [3].

This paper focuses specifically on this challenge of CPS from modelling up to the control design as hybrid systems (HS) [4, 5]. The most convenient hybrid systems framework for such a task is hybrid automata (HA) which naturally deals with a continuous and discrete dynamics of hybrid systems [6]. However, such a mathematical representation is not appropriate for analysis and control design of CPS. For these tasks, different but equivalent mathematical representations were introduced, e.g. piecewise affine (PWA) systems [7].

There have been proposed several approaches to unify the procedure to model, analyse and design control algorithms for hybrid systems. Within mentioned procedures being one published in [8], however, this approach does not utilize analysis of the systems in the open loop and during control synthesis no metaheuristic algorithms to tune control parameters were used. Another approach, published in [9], utilizes supervisory control of hybrid systems but omits the analysis part. Methodology utilizing modelling and diagnosis of hybrid systems was proposed in [10].

Goal of this article is to propose and introduce the unified methodology for the whole process from modelling

up to the control design and therefore cover all the steps to ensure proper design and analysis of CPS as a hybrid system. This process was partially introduced in [2, 11] and will be completed with regards to other research challenges. The methodology consists of several steps, namely determination of HA elements such as possible discrete modes and transitions between them, followed by assigning continuous dynamics to those modes. At this point it is possible to simulate and analyse the hybrid system.

After validation of the system, design control utilizing appropriate control algorithms can be implemented onto the hybrid system. Between the most used control algorithms for hybrid systems being model predictive control based on multiparametric optimization [12] and piecewise optimal linear quadratic (LQR) optimal control [13]. These methods were chosen as representatives of control algorithms for hybrid systems. However, there are many others such as semi-Markov mode switching for linear parameter-varying systems [14] or supervisory control [15].

While designing control law, a metaheuristic method for tuning control law parameters can be utilized. Between these metaheuristic methods belong e.g. particle swarm optimization (PSO) [16], artificial bee colony [17], ant colony optimization [18] or grey wolf optimization approach [19]. We have chosen PSO algorithm as a representative example for tuning control algorithm parameters. This algorithm was then applied onto all controllable discrete modes of the HS.

*Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovakia, dominik.voscek@tuke.sk, anna.jadlovskaa@tuke.sk, dominik.griglik@stuba.tuke.sk

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web sessions will cover the use of nitrox for decompression diving diving within a maximum operating depth for a selected nitrox mix how to plan a dive using the bsac nitrox tables or a nitrox computer and the extra considerations when managing nitrox diving

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web the british sub aqua club or bsac has been recognised since 1954 by uk sport as the national governing body of recreational diving in the united kingdom the club was founded in 1953 and at its peak in the mid 1990s had over 50 000 members declining to over 30 000 in 2009 it is a diver training organization that operates through its associated

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web the sports diver nitrox workshop is designed to be delivered to sports divers or recognised equivalents and above who have either attended the ocean diver nitrox workshop or hold the bsac basic nitrox certification or recognised equivalent workshop overview

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web this is an introduction to the nitrox diver workshop with the primary aim of updating existing bsac divers already qualified as ocean diver or equivalent who have not covered the nitrox component within the revised diver training programme dtp

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web current bsac member bsac sports diver or equivalent nitrox diver or equivalent and depth experience to 30 metres gold standard buoyancy from the buoyancy and trim workshop and be qualified as a bsac wreck diver or equivalent

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web the diving qualifications listed below are considered to be of a similar standard to those of bsac however the list is not definitive there are many diving qualifications issued by agencies all over the world if you can't find yours here

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web aims unless you have attended a skill development course in the use of nitrox you will not have access to breathing gases where the oxygen content is greater than air nitrox 21 the key aims of this workshop are to enable bsac ocean divers or similar to appreciate the benefits of diving on nitrox

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web this workshop brings divers who do not have a nitrox qualification to the same level as a bsac ocean diver it is suitable for pre 2007 ocean divers or those from other agencies who have not been taught to use nitrox course authorisation instructors must record completion of this workshop using the workshop attendance form

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web on this approximately 90 minute theory workshop you will learn what nitrox is discover the benefits of diving on nitrox understand any physiological and equipment related implications of using nitrox learn how to plan a no stop

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web techniques are explained in detail from towing an unconscious diver in the water to assisted ascents and from rescuing an injured diver from the depths to landing him on boat or beach the book also covers rescue management including the use of rescue equipment and after care deco for divers aug 04 2022 mixed gas diving jul 11 2020

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web aim the key objectives of this workshop are to further the learning of qualified divers the workshop extends the your knowledge by expanding on the implications of nitrox diving as the maximum operating depth is increased to 35 metres *sports diver british sub aqua club* - Jun 19 2023

web if you already have some diving experience with an entry level qualification and want to take your underwater adventures to the next level sports diver is your next step in bsac's diver training programme there are two routes to becoming a sports diver either from advanced ocean diver or directly from ocean diver

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