Technical University of Košice

Faculty of Electrical Engineering and Informatics

SCYR

23rd Scientific Conference of Young Researchers
Proceedings from Conference

ISBN 978-80-553-4377-8

2023

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SCYR 2023: 23rd Scientific Conference of Young Researchers
Proceedings from Conference

Published: Faculty of Electrical Engineering and Informatics
Technical University of Košice
Edition I, 196 pages, number of CD Proceedings: 50 pieces

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ISBN 978-80-553-4377-8

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Foreword

Dear Colleagues,

SCYR (Scientific Conference of Young Researchers) is a scientific event focused on exchange of information among young researchers from Faculty of Electrical Engineering and Informatics at the Technical University of Košice – series of annual events that was founded in 2000. Since 2000, the conference has been hosted by FEEI TUKE with rising technical level and unique multicultural atmosphere. The 23rd Scientific Conference of Young Researchers (SCYR 2023) was held on April 20, 2023 at University Conference Centre, Technical University of Košice. The mission of the conference, to provide a forum for dissemination of information and scientific results relating to research and development activities at the Faculty of Electrical Engineering and Informatics, has been achieved. Approx. 70 participants, mostly by doctoral categories, were active in the conference.

Faculty of Electrical Engineering and Informatics has a long tradition of students participating in skilled labor where they have to apply their theoretical knowledge. SCYR is an opportunity for doctoral and graduating students to train their scientific knowledge exchange. Nevertheless, the original goal is still to represent a forum for the exchange of information between young scientists from academic communities on topics related to their experimental and theoretical works in the very wide spread field of a wide spectrum of scientific disciplines like informatics sciences and computer networks, cybernetics and intelligent systems, electrical and electric power engineering and electronics.

Traditionally, contributions can be divided in 2 categories:

- Electrical & Electronics Engineering
- Computer Science

with approx. 70 technical papers dealing with research results obtained mainly in the University environment. This day was filled with a lot of interesting scientific discussions among the junior researchers and graduate students, and the representatives of the Faculty of Electrical Engineering and Informatics. This Scientific Network included various research problems and education, communication between young scientists and students, between students and professors. Conference was also a platform for student exchange and a potential starting point for scientific cooperation. The results presented in papers demonstrated that the investigations being conducted by young scientists are making a valuable contribution to the fulfillment of the tasks set for science and technology at the Faculty of Electrical Engineering and Informatics at the Technical University of Košice.

We want to thank all participants for contributing to these proceedings with their high quality manuscripts. We hope that conference constitutes a platform for a continual dialogue among young scientists.

It is our pleasure and honor to express our gratitude to our sponsors and to all friends, colleagues and committee members who contributed with their ideas, discussions, and sedulous hard work to the success of this event. We also want to thank our session chairs for their cooperation and dedication throughout the entire conference.

Finally, we want to thank all the attendees of the conference for fruitful discussions and a pleasant stay in our event.

Liberios VOKOROKOS
Dean of FEEI TUKE

April 20, 2023, Košice

Contents

Modeling and Experimental Identification of Nonlinear Dynamical Systems

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***Abstract*—The presented paper deals with the results obtained during the second year of my PhD study in the field of nonlinear dynamical system experimental identification. The methodology of the experimental identification is presented in four consecutive steps with a description. Application of the presented methodology is summarized in approximation model identification of the magnetic levitation system. Also, the ALFRED application is described with the outlook of using it in experimental identification.**

***Keywords*—Nonlinear Dynamical Systems, Experimental Identification, Modeling, Digital Twin, Detector Control System**

I. INTRODUCTION

The present trend in the rapid development of computer technologies results in the system design phase being increasingly approached fully digitally using the CAD software. Many software tools allow the created design to be simulated in a virtual environment to test the performance of the design without the need to build a physical model [1]. This opens the question of the credibility of the results that solely rely on the system model. The model is therefore a virtual representation of the real system - digital twin [2].

The model can be obtained in two standard ways - *analytical identification* and *experimental identification* [1]. Analytical identification (or first principles modeling) uses physics laws to derive a model in the form of differential or difference equations. Conversely, experimental identification is based on data. It is the growing number of sensors and the interconnection of systems that enable one to collect a large amount of data to create model by means of experimental identification [3].

II. PREVIOUS ANALYSIS AND ACHIEVED RESULTS

The experimental identification is a set of data-driven methods and algorithms. It is an iterative approach consisting of four steps depicted in Fig. 1. Each step is supported by a priori knowledge gained from experience with similar systems or as a result of analytical identification [1].

The data collection step combines experiment design, data gathering, and data preprocessing. The experiment design takes into consideration dynamics and constraints of the system to design the most informative experiment that is also safe and economically viable [4]. The data gathering makes use of sensors to digitally record data from the system. The data is later preprocessed using signal processing algorithms to mitigate the effects of the noise or to transform data [3].

The model structure selection step is influenced by the amount of information taken from the analytical identification.

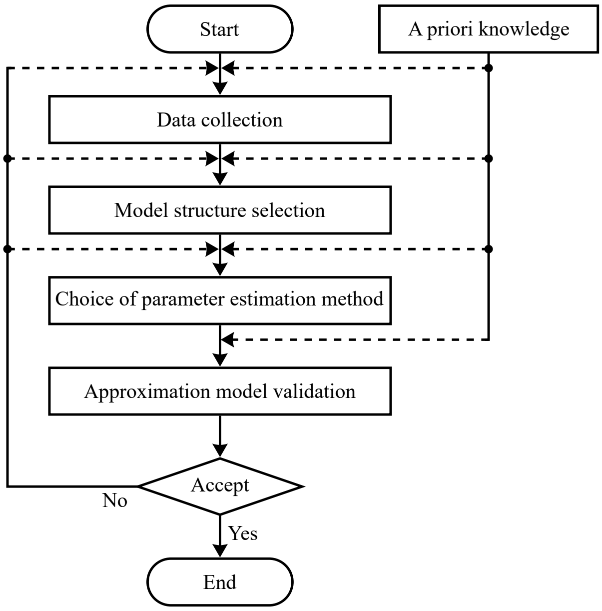

Fig. 1. Experimental identification loop [3].

In case the model structure is obtained using analytical identification, the model is considered to be a gray-box model and only the parameters are to be estimated [5]. On the other hand, black-box models are obtained using data-driven methods to estimate parameters and the model's internal structure [4].

The choice of parameter approximation method step is dependent on the selected model structure. Generally, the parameter value estimation minimizes the output prediction error $\varepsilon(k) = y(k) - \hat{y}(k)$ [6]. Methods of local or global optimization are utilized to estimate parameter values.

Finally, the goal of model validation is to prove the approximation model meets application requirements (e.g., to design a controller or perform diagnostics). Qualitative methods are strictly goal-oriented and results are drawn from an expert's judgment [4]. Quantitative methods on the other hand use statistical metrics and are better suited for the performance comparison of multiple approximation models [3].

III. SOLVED TASKS AND RESULTS

During the second year of the PhD study, the author has focused on the identification of the magnetic levitation system (MLS) created by the Humusoft company. The mathematical model has been derived first using the physics laws. The resulting mathematical model included parameters that could not

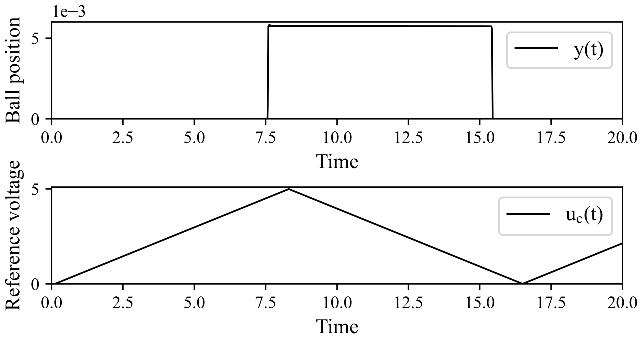

Fig. 2. Sample of triangle signal used to identify static properties of the magnetic levitation system.

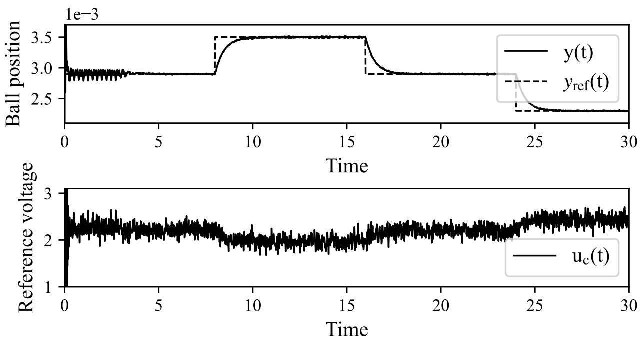

Fig. 3. Application of the LQI controller on the real magnetic levitation system.

be measured directly. Therefore it was necessary to perform experimental identification to be able to design stabilizing controller for this system. Further details will be published in the Tkáčik et.al. article in the AEI journal that is currently under the review.

Experimental identification of the MLS was performed according to the methodology presented in the previous chapter. The dynamics of the MLS stands out as very fast and unstable. Since it is not possible to create even a crude controller for this system, we opted for the experimental identification in the open loop setup. Triangle and pseudorandom binary (PSRB) signals were applied to measure the static and dynamic properties of the system respectively [7]. Sample of the triangle signal applied to the MLS is shown in Fig. 2.

The analytically identified model structure was chosen as the final structure of the approximation model. Initial parameter values were estimated from static analysis data. Later these values were refined using the nonlinear least squares method in conjunction with PSRB data [8].

The approximation model validation was performed on the different realization of the PSBR signal. The qualitative approach of visual comparison between approximate and real output was inconclusive. For the final validation, it was decided to design a stabilizing LQI control algorithm. Application results of the designed LQI control algorithm evaluated on the real system are shown in Fig. 3. The created approximation model in conjunction with designed communication interfaces is the digital twin of the MLS.

The presented MLS is part of the research and development platform at the CMCT&II that the author has been finalizing during the last year. This platform will be used for the validation of intelligent identification and control methods.

The author is also actively participating in the project called *Experiment ALICE on LHC in CERN: Study of strongly interacting matter at extreme energy densities* in collaboration with the CERN. The author is working on the FRED program module of the ALFRED application that is part of the Detector Control System (DCS) used to control physics experiments. The FRED module is used to generate command sequences to control detector components based on requests from WinCC OA [9].

Last year's contribution was mainly in the performance and testing of the FRED module. This included the creation of scripts for automatic testing and the tool to simulate ALF behavior thus mitigating the need for actual hardware components of the detector during testing.

IV. Future research steps

Future research will be devoted to the exploration of the knowledge transfer from gray-box models to black-box models and to improve the overall quality of the approximation model. In [10] the idea to combine gray-box models with neural network-based black-box models proved to be successful. Therefore, we see potential in the combination of analytical and experimental identification approaches, especially with the use of AI-based methods. Last but not least, the author will be participating in the commissioning of the FRED program module as part of the DCS and also in the experimental identification of detector electronics.

V. Conclusion

The presented paper deals with a methodology for experimental identification. It presents experimental identification as the sequence of four steps supported by a priori knowledge. The experimental identification of the magnetic levitation system as the gray-box model is presented alongside the improvements made to the ALFRED application.

Acknowledgment

This work has been supported by the project ALICE experiment at the CERN LHC: The study of strongly interacting matter under extreme conditions (ALICE KE FEI TU 0410 / 2022).

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