Technical University of Košice

Faculty of Electrical Engineering
and Informatics

SCYR

24th Scientific Conference of Young Researchers
Proceedings from Conference

ISBN 978-80-553-3474-5

2024

Sponsors & Organizers

SCYR 2024: 24th Scientific Conference of Young Researchers
Proceedings from Conference

Published: Faculty of Electrical Engineering and Informatics
Technical University of Košice
Edition I, 182 pages, number of CD Proceedings: 50 pieces

Editors: Assoc. Prof. Ing. Karol Kyslan, PhD.
Assoc. Prof. Ing. Emília Pietriková, PhD.
Ing. Lukáš Pancurák

ISBN 978-80-553-3474-5

Scientific Committee of SCYR 2024

General chair: Prof. Ing. Liberios Vokorokos, PhD.

Editorial board chairman: Assoc. Prof. Ing. Karol Kyslan, PhD.

Committee Members & Reviewers:

Ing. Tibor Gujdan, Fpt Slovakia s.r.o.
Ing. Juraj Bujňák, PhD., Siemens Healthineers
Assoc. Prof. Ing. Jaroslav Džmura, PhD.
Prof. RNDr. Vladimír Lisý, DrSc.
Prof. Ing. Alena Pietriková, CSc.
Assoc. Prof. Ing. Marek Pástor, PhD.
Assoc. Prof. Ing. František Babič, PhD.
Assoc. Prof. Ing. Eva Chovancová, PhD.
Assoc. Prof. Ing. Emília Pietriková, PhD.
Assoc. Prof. Ing. Peter Feciľak, PhD.
Assoc. Prof. Ing. Peter Papcun, PhD.
Assoc. Prof. Ing. Matúš Pleva, PhD.
Assoc. Prof. Ing. Ján Papaj, PhD.
Assoc. Prof. Ing. Stanislav Ondáš, PhD.

Organizing Committee of SCYR 2024

Members:

Assoc. Prof. Ing. Karol Kyslan PhD.
Assoc. Prof. Ing. Emília Pietriková, PhD.
Ing. Ivana Olšiakova
Ing. Peter Provázek
Ing. Lukáš Pancurák
Ing. Simona Saparová
Ing. Šimon Gans
Ing. Matúš Dopiriak
Ing. Kristián Mičko

Contact address: Faculty of Electrical Engineering and Informatics
Technical University of Košice
Letná 9
040 01 Košice
Slovak Republic

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 24^{th} Scientific Conference of Young Researchers (SCYR 2024) was held on April 19, 2024 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. 60 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. 60 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 19, 2024, Košice

Contents

Contribution to Experimental Identification of Nonlinear Dynamical Systems

[1]*Tomáš TKÁČIK (3rd year),*
Supervisor: [2]*Anna JADLOVSKÁ, Consultant:* [3]*Ján JADLOVSKÝ*

[1,2,3]Dept. of Cybernetics and Artificial Intelligence, FEEI TU of Košice, Slovak Republic

[1]tomas.tkacik@tuke.sk, [2]anna.jadlovska@tuke.sk, [3]jan.jadlovsky@tuke.sk

***Abstract*—This contribution presents results obtained during the last year of the author's PhD study in the field of nonlinear dynamical system identification. A brief introduction to the methodology of the experimental identification is presented with its application in the helicopter laboratory model identification. Finally, improvements to the ALFRED and DARMA applications as part of project ALICE CERN are presented.**

***Keywords*—Nonlinear Dynamical Systems, Experimental Identification Methodology, Helicopter Laboratory Model, Detector Control System**

I. Introduction

Mathematical models present a fundamental tool in various scientific and engineering disciplines. They capture important properties of the real systems in a compact form. This allows models to be useful in many tasks including analysis, prediction, diagnosis, process optimization, etc. [1]. Models are a crucial part of the model-based design paradigm that prioritizes the use of models over creating several iterations of the real system, especially when designing complex systems [2].

Two primary options exist to create the mathematical model of the real dynamical system: analytical and experimental identification [2]. Former relies on deriving a mathematical model using physics laws in the form of differential or difference equations. On the contrary, experimental identification is a data-driven paradigm that uses experimental data to infer both structure and parameters from data. The availability of relatively cheap computational power and the abundance of experimental data fueled the popularity boom of the experimental identification paradigm in recent years [3].

II. Previous analysis and achieved results

The general experimental identification methodology consists of four steps: data collection, model structure selection, choice of parameter estimation method, and approximation model validation [1], [4]. Each step is supported by the a priori knowledge gained by technical insight into the identified system and individual steps can be repeated if needed.

The data collection step requires the design of an experiment that meets multiple criteria: economical, safety, regulatory, captures target system dynamics, etc. The choice of a suitable sampling period T_s and further preprocessing algorithms are also to be considered in this step.

The amount and quality of data affect what model structures can be used. Generally, model structures derived using analytical identification methods require less data compared to data-driven techniques [1]. Conversely, self-organizing model structures (e.g., neural networks) allow to model more complex processes that would otherwise be simplified or neglected.

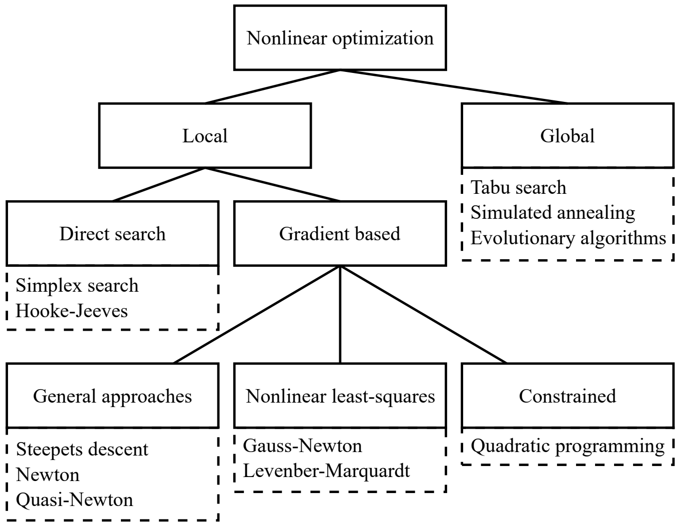

Fig. 1. Overview of nonlinear optimization methods [1].

Based on the selected model structure, a parameter approximation method is selected, see Fig. 1. Generally, all approximation methods are based on the principle of output prediction error minimization to estimate parameter values [5].

The goal of the model validation step is to gain confidence in the identified model. Both quantitative and qualitative methods are used to validate the identified model [2].

III. Solved tasks and results

During the last year, the author focused on the finalization of the case study of the CE 152 Magnetic Levitation Laboratory Model identification from Humusoft [6] and the results have been accepted for publishing in the AEEE journal [7]. This case study verified the proposed identification methodology on a single-input single-output (SISO) system with fast dynamics. However, it is necessary to verify the generality of the proposed methodology also on multiple-input multiple-output (MIMO) system. For this purpose, the CE 150 Helicopter Laboratory Model from Humusoft [8] was chosen. It is a nonlinear dynamic system with two subsystems (elevation and azimuth) with one actuator per subsystem with direct influence. Cross-coupling between both subsystems is expected [8] and is subject to experimental identification. Previously in

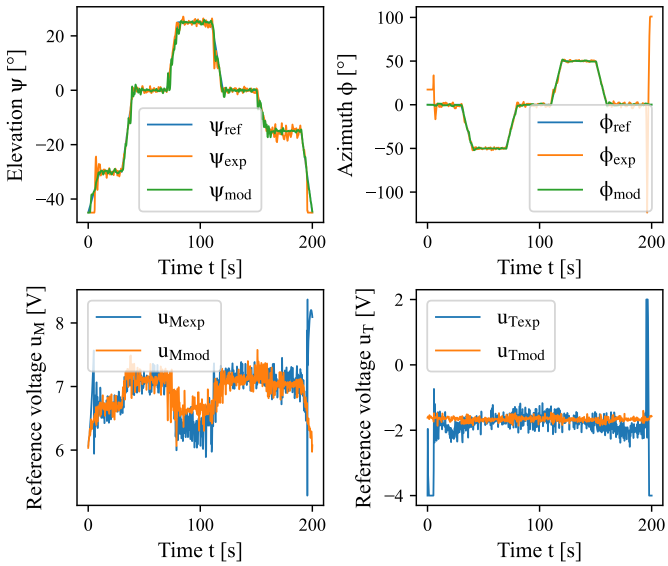

Fig. 2. Closed-loop validation of the identified helicopter model - comparison of simulation and real model output.

our research group, the Helicopter Laboratory Model was identified as a black-box model in [9]. On the contrary, the identification of a gray-box model is presented in this paper.

The data collection step relies on static and dynamic experiments. Static experiments include elevation subsystem balancing with the addition of counterweights and measuring the dependence of rotor speed and thrust using a strain gauge. Dynamic experiments capture the transient behavior of both rotors at different input voltages, the transient behavior of the elevation subsystem in a stable region, and the behavior of the azimuth subsystem with varying reference voltages. The mentioned experiments were performed for individual subsystems separately with the other subsystem locked to avoid cross-coupling. To measure interactions between subsystems, the reference voltage of both rotors was periodically varied to induce stable oscillations. Data was recorded at a sampling period $T_s = 0.01[s]$ without additional pre-processing.

The chosen structure of the model is based on the analytical model [8]. Since modeling helicopter rotors analytically is very difficult [10], a 1st order linear approximation model was extended with nonlinear damping approximated by a polynomial. The dependence of the motor thrust and speed was also approximated by a polynomial.

The model parameters were initially estimated by the surrogate optimization and were later refined using the nonlinear least squares method. To reduce the complexity of the optimization problem, rotors and subsystems were identified separately. Lastly, parameter values of modeled interactions were estimated using a similar technique.

To validate the identified model, it was necessary to design a control algorithm as both subsystems are unstable in the open loop. A polynomial control algorithm with gain scheduling based on instantaneous linearization was chosen [11]. The validation results are shown in Fig. 2. The identified model correctly approximates the dynamics of the real system.

The author also contributed to the ALICE CERN project and implemented the new CERN SSO system into the DARMA information system (IS) alongside improvements in performance, graphical interface, and technological upgrades [12]. DARMA IS serves as a tool for offline access to process data from individual detectors of the ALICE experiment. At the same time, the author participated in the throughput testing of the ALFRED application using the upgraded ALF Simulator. All tests were performed on the production network at CERN. Additionally, the author has updated the database interface in the FRED framework to ensure compatibility with C++20. Results obtained by the research group were published in [13].

IV. Future Research Steps

The author is currently finalizing modifications in the identification methodology of nonlinear dynamic systems, preparing case studies on identification of Aerodynamic and Magnetic Levitation and the Helicopter Laboratory Model, exploring the possibilities of using intelligent models based on a neural networks [10] in the task of experimental identification of the Helicopter Laboratory Model, and finalizing tasks within the ALICE CERN project.

V. Conclusion

This paper summarized the identification methodology of nonlinear dynamic systems and its application in the identification of the Helicopter Laboratory Model in the form of a gray-box model. It also summarizes the progress on the DARMA and ALFRED applications in the ALICE CERN project.

Acknowledgment

This work was supported by the *Slovak Research and Development Agency* under the contract No. *APVV-19-0590* and the project *ALICE experiment at the CERN LHC: The study of strongly interacting matter under extreme conditions, ALICE TUKE 0410/2022.*

References

[1] O. Nelles, *Nonlinear system identification: from classical approaches to neural networks, fuzzy models, and gaussian processes.* Springer Nature, 2020.

[2] L. Ljung, T. Glad, and A. Hansson, *Modeling and Identification of Dynamic Systems.* Studentlitteratur AB, 2021.

[3] C. Legaard, T. Schranz, G. Schweiger, J. Drgoňa, B. Falay, C. Gomes, A. Iosifidis, M. Abkar, and P. Larsen, “Constructing neural network based models for simulating dynamical systems,” *ACM Computing Surveys*, vol. 55, no. 11, pp. 1–34, 2023.

[4] T. Tkáčik, “Modeling and experimental identification of nonlinear dynamical systems,” *23rd Scientific Conference of Young Researchers: proceedings from conference - Košice (Slovensko)*, pp. 103–104, 2023.

[5] T. Rogers, G. Holmes, E. Cross, and K. Worden, *On a Grey Box Modelling Framework for Nonlinear System Identification.* Springer, 03 2017, pp. 167–178.

[6] Humusoft, “Magnetic Levitation CE 152 - Educational Manual,” 2008.

[7] T. Tkáčik, A. Jadlovská, and J. Jadlovský, “Modeling, identification and validation of the modified magnetic levitation model,” *Advances in Electrical and Electronic Engineering*, 2024, accepted for publication on 29 January 2024.

[8] Humusoft, “Helicopter CE 150 - Educational Manual,” 2012.

[9] K. Dolinský and A. Jadlovská, “Application of results of experimental identification in control of laboratory helicopter model,” *Advances in electrical and electronic engineering*, vol. 9, no. 4, pp. 157–166, 2011.

[10] N. Mohajerin and S. L. Waslander, “Multistep prediction of dynamic systems with recurrent neural networks,” *IEEE Transactions on Neural Networks and Learning Systems*, vol. 30, no. 11, pp. 3370–3383, 2019.

[11] K. H. McNichols and M. Fadali, “Selecting operating points for discrete-time gain scheduling,” *Computers & Electrical Engineering*, vol. 29, no. 2, pp. 289–301, 2003.

[12] M. Kopecký, T. Tkáčik, and J. Jadlovský, “Modifikácia informačného systému darma pre experiment alice cern,” *Electrical Engineering and Informatics 14: Proceedings of the Faculty of Electrical Engineering and Informatics of the Technical University of Košice*, pp. 267–271, 2023.

[13] M. Tkáčik, J. Jadlovský, S. Jadlovská, A. Jadlovská, and T. Tkáčik, “Modeling and analysis of distributed control systems: Proposal of a methodology,” *Processes*, vol. 12, no. 1, 2024.

Author's index

SCYR 2024: 24rd Scientific Conference of Young Researchers

Proceedings from Conference

Published: Faculty of Electrical Engineering and Informatics
Technical University of Košice
Edition I, 182 pages
Number of CD Proceedings: 50 pieces

Editors: Assoc. Prof. Ing. Karol Kyslan, CSc.
Assoc. Prof. Ing. Emília Pietriková, PhD.
Ing. Lukáš Pancurák

ISBN 978-80-553-3474-5