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STADIUS
Center for Dynamical Systems, Signal Processing and Data Analytics

STADIUS Newsletter

June 2023

RESEARCH ▪ NEWS ▪ PROJECTS ▪ STAFF UPDATE ▪ PUBLICATIONS

Welcome to the last edition of the STADIUS Newsletter in this academic year!

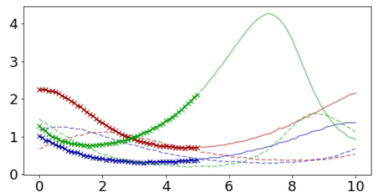
We would like to wish you all a healthy and productive summer, and for those who plan some holidays: enjoy them and return safely.

See you all around!

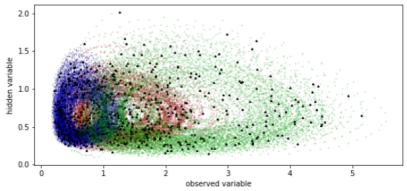
Research of the month

α	β	γ	δ
0.6	0.9	0.5	0.4
0.6	0.9	0.5	0.8
0.6	0.9	0.9	0.4

$$\dot{x} = \alpha x - \beta xy$$
$$\dot{y} = \gamma xy - \delta y$$



(a)

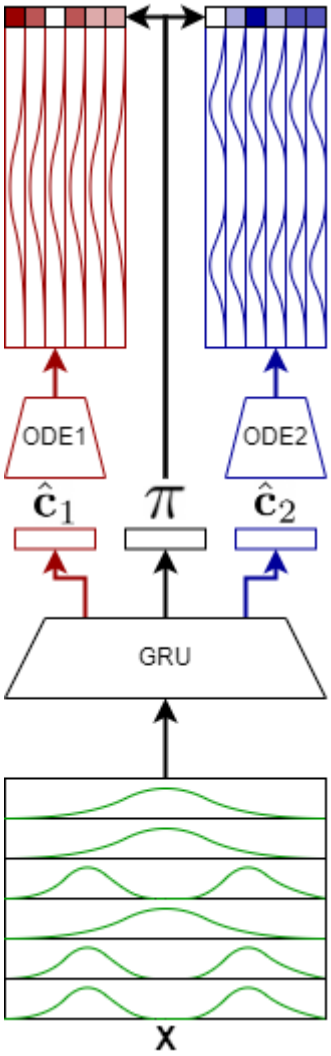


(b)

András Formanek: "Identification of Hidden Clusters of Time Series with Hybrid Neural Networks Integrating Expert ODEs"

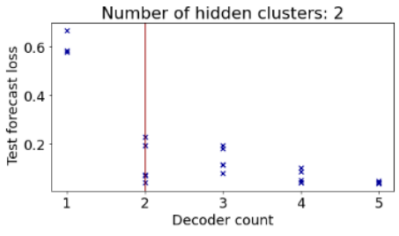
Deep learning-based approaches for time series analysis notoriously suffer from interpretability issues because of their black-box nature. In our work, we propose a novel hybrid neural network architecture with embedded expert knowledge incorporated in the form of Ordinary Differential Equations (ODEs). This method is designed to cluster the data, identify the parameters of the generating systems, and reconstruct partially observed time series trajectories

accordingly. We demonstrate empirically that our approach is not only more interpretable but also better at forecasting than its black-box counterparts.

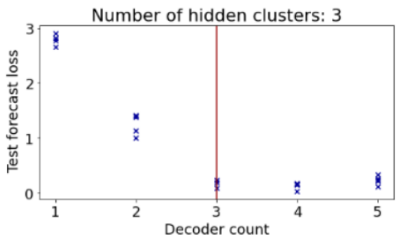


In practical system identification scenarios, partially observed time series are often acquired from a set of similar dynamical systems forming clusters in the parameter space (e.g., healthy vs. diseased patients). The problem of identifying these clusters and that of identifying the model parameters are tightly coupled. However, it is challenging to learn complex dynamics from a single short time series, while the correct grouping of these segments is not known a priori. We assume that the time series are generated by a dynamics given by a finite set of Ordinary Differential Equations (ODEs) with the same known functional form, but varying parameters and initial conditions. This way we can significantly reduce the number of systems that needs to be identified and also utilize short time series segments.

The proposed network relies on an encoder-decoder architecture, where the inner representation is decomposed into cluster membership probabilities (π in Figure) and initial states (c in Figure) and the decoder simulates possible reconstruction trajectories based on the current parameter estimations. We use GRU as the encoder network, followed by a fully-connected network outputting the inner representation. The decoder network consists of K expert ODEs with distinct parameters. This way, while the GRU is still a black-box, the inner representation and the ODEs are fully interpretable.



(a)



(b)

Recently we have shown our model's ability to cluster time series and to forecast the future of individual trajectories. We then investigated the impact of the most important hyperparameters of our method and the sensitivity to initial conditions. Also, we have shown how the number of decoders can be tuned in practice using the profile of the forecasting error on a hold-out set.

Our goal is to scale up the model for biological systems with more, potentially hidden, variables with a possible relevance in clinical practice.

News



Promotions @ STADIUS

We are very glad to announce that both **Alexander Bertrand** and **Maarten De Vos,** after positive evaluation, will be promoted to Professor (hoogleraar) from October 1 this year.

Many Congratulations!

Bart De Moor speaks about AI in Flemish Parliament

On the 6th of June Prof. Dr. **Bart De Moor,** representing the Flemish AI Academy, spoke in the Flemish Parliament about the **rapid evolutions in AI**, making lifelong learning indispensable. The impact of AI will require structural AI investments in education, research, innovation, and awareness-raising for the Flemish society. The other invitees speaking about the **current challenges of artificial intelligence** were: Jeroen Fiers from VLAIO Sabine Demey from the Flemish AI research program, Rob Heyman from the Knowledge Center Data and Society Jonathan Berte of Robovision.
You can see the recording of this hearing here.



STADIUS alumnus Stein Aerts becomes AI director for AI VIB

Our former PhD student, now Professor **Stein Aerts,** has just been appointed as the **AI director of the new department AI VIB**.
Stein obtained his PhD in bio-informatics in Stadius in 2004. He belonged to the first generations of bioinformaticians who have now a leading role in academia, companies, and governmental institutes.
Read all about Stein's selection and nomination.

Bart De Moor becomes a member of Academia Europaea

Bart De Moor was elected as a member of the prestigious **Academia Europaea.** The aim of the **Academy of Europe** is to promote European research, advise governments and international organisations in scientific matters, and further interdisciplinary and international research.

We wish the best of luck to the researchers who are leaving STADIUS

Best of luck!

- **Arun Pandey** defended his PhD on 05/06 and is now working at ASML in The Netherlands.
- **Tim Hermans,** a researcher from the group of Maarten De Vos has just defended his PhD on 21/06 and is leaving STADIUS end of June.

Tim, Arun, we wish you all the best in your future carreers.

Recently approved projects

We are glad to share the news that following projects were recently approved:

- **IDN-Project** *"Online tracking of auditory attention via electroencephalography (EEG) in individuals and groups of learners"*
  - Coordinator: Alexander Bertrand
  - Partners: Bert De Smedt and Elien Bellon (UZ Leuven), Simon Geirnaert (STADIUS)

- **BOF-PDM Mandate** "Data-centric distributed signal processing for spatial filtering in wireless sensor networks"
  - **Cem Musluoglu** (prom. Alexander Bertrand)

Publication Digest

Here's the monthly STADIUS Publications Digest, including new reports that have been added to the publications database.

Please remember to have your own reports added in the publications database and make sure your entries are kept up to date (status submitted/accepted/published) at all times.

Contact Ida for new additions and updates, do not add/update database content yourself.

23-84

Chen Y., Tao Q., Tonin F., Suykens J.A.K., "Primal-Attention: Self-attention through Asymmetric Kernel SVD in Primal Representation", Technical Report 23-84, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-85

Tengan E., Dietzen T., Elvander F., van Waterschoot T., "Direction-of-arrival and power spectral density estimation using a single directional microphone and group-sparse optimization", Technical Report 23-85, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-86

Tengan E., Dietzen T., Elvander F., van Waterschoot T., "Multi-source direction-of-arrival estimation using group-sparse fitting of steered response power maps", Technical Report 23-86, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-87

Tonin F., Lambert A., Patrinos P., Suykens J.A.K., "Extending Kernel PCA through Dualization: Sparsity, Robustness and Fast Algorithms", Technical Report 23-87, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023. Accepted for publication in *International Conference on Machine Learning* (ICML 2023).
Lirias number: 4090739.

23-88

Evert E., Vervliet N., Domanov I., De Lathauwer L., "Uniqueness result and algebraic algorithm for decomposition into multilinear rank-$ terms and joint block diagonalization", Technical Report 23-88, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-89

Tao Q., Tonin F., Patrinos P., Suykens J. A.K., "Nonlinear SVD with Asymmetric Kernels: feature learning and asymmetric Nystrom method", Technical Report 23-89, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-90

Dietzen T., De Sena E., van Waterschoot T., "Low-Complexity Steered Response Power Mapping based on Low-Rank and Sparse Interpolation", Technical Report 23-90, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-91

Tonin F., Patrinos P., Suykens J. A.K., "Combining Primal and Dual Representations in Deep Restricted Kernel Machines Classifiers", Technical Report 23-91, ESAT-STADIUS, KU Leuven (Leuven, Belgium), 2023.

23-93

Rocco G., Bernardi G., Ali R., van Waterschoot T., Polo E.M., Barbieri R., Paglialonga A., "Characterization of the Intelligibility of Vowel-Consonant-Vowel (VCV) Recordings in Five Languages for Application in Speech-in-Noise Screening in Multilingual Settings", *Applied Sciences*, vol. 13, no. 5344, 2023, pp. 1-13.
Lirias number: 4087527.

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