TECHNISCHE UNIVERSITÄT MÜNCHEN
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MASTER'S THESIS

Robust Learning under Sensor Reduction for Multi-Modal Nonlinear Dynamical Systems

Problem description:

Many modern cyber-physical systems are equipped with rich multi-modal sensing (e.g. inertial, pressure, visual sensors) during development, while deployed systems must operate with reduced sensor sets due to cost, energy and robustness constraints. This leads to a distribution shift between training and deployment, especially when entire modalities are removed at test time. Robust learning under missing features and feature deletion has been investigated in the machine learning community (e.g. robust classifiers under feature deletion, modality-missing multimodal learning, robust Bayesian estimators for incomplete data). In this project, we study this problem for nonlinear motion systems with multi-modal sensors, using surfboard maneuver analytics as a representative case of humanboard interaction: during initial data collection, multiple sensors (board IMU, rear-foot pressure pad, optional additional sensors) are available, while the final product is constrained to a subset (e.g. only board IMU + one pressure pad).

This thesis will be performed in collaboration with TRAX Technologies
https://traxsurf.com/

Tasks:

- Literature review on multi-modal learning and robustness to missing features,
- Preprocessing and synchronisation of multi-modal motion datasets (IMU and pressure sensors),
- Implementation of baseline models and systematic sensor ablation studies,
- Evaluation of training strategies (e.g., distillation) to improve performance on reduced sensor sets,
- Analysis of results and documentation of design guidelines for minimal sensor configurations.

Bibliography:

[1] Amir Globerson and Sam Roweis. Nightmare at test time: robust learning by feature deletion. In *Proceedings of the 23rd International Conference on Machine Learning*, ICML '06, page 353360, New York, NY, USA, 2006. Association for Computing Machinery.

[2] Mengmeng Ma, Jian Ren, Long Zhao, Sergey Tulyakov, Cathy Wu, and Xi Peng. Smil: Multimodal learning with severely missing modality. *Proceedings of the AAAI Conference on Artificial Intelligence*, 35(3):2302–2310, May 2021.

[3] Renjie Wu, Hu Wang, Hsiang-Ting Chen, and Gustavo Carneiro. Deep multimodal learning with missing modality: A survey, 2024.

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Start:	tbc
Intermediate Report:	tbc
Delivery:	tbc

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