

PhD Opportunity: A Digital Twin-Driven Approach to Predictive Safety and Control Optimisation in Human-Robot Collaborative for Diagnostics and Treatment (HRCDT)



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Dr Ming-wei Chang



Prof. James McLaughlin

Main Essence of Research Activities

- Conduct research at the Multi-Agent and Advanced Robotics Centre (MAvRiC) using newly acquired Cobots and AMRs
- Develop DT-driven framework to enhance safety and optimise control in HRCDT
- Integrate real-time data from multi-modal sensors for monitoring and prediction
- Employ advanced hybrid techniques (model-based + data driven) to enhance robustness
- DT-capable HPC for computationally intensive tasks

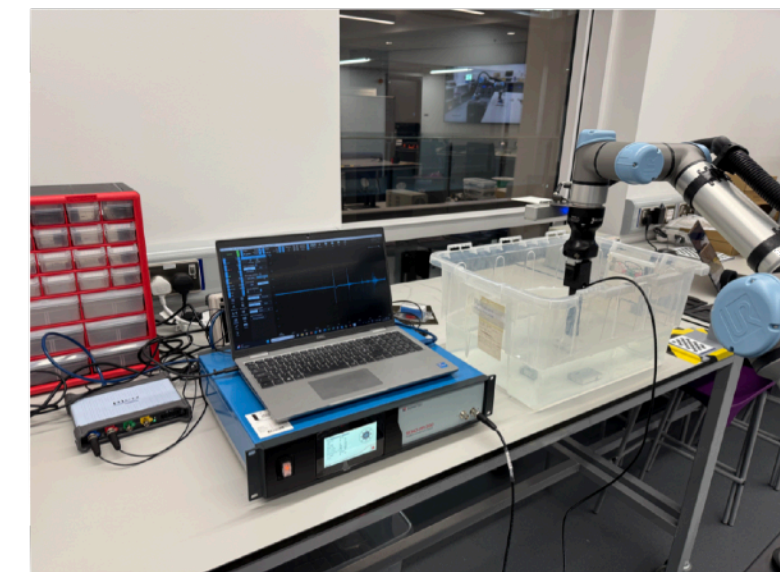
Select Equipment at MAvRiC:



ER-FLEX Autonomous Systems



Turtlebots



US Pulsar and Transducer



File photos of human-robot collaboration in the medical sector

Other Collaborators and Partners



Control Systems, Fault Diagnosis, Digital Twin, and Simulation Testbed

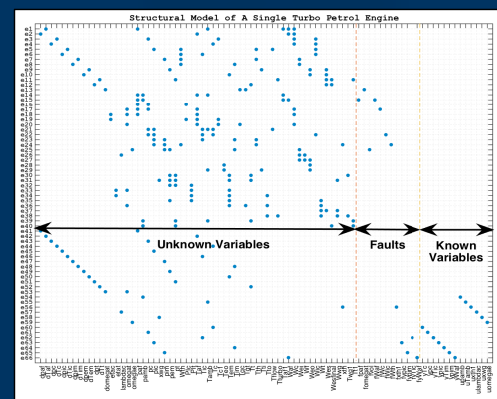
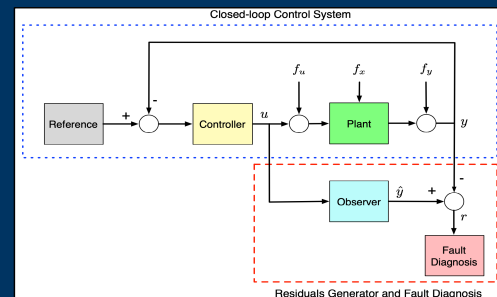
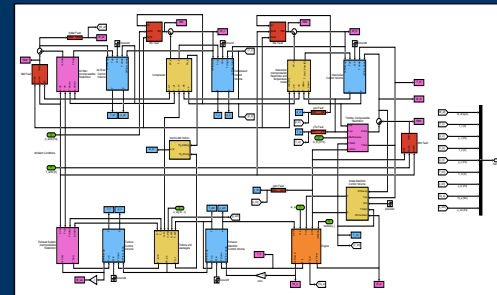
Physical Systems



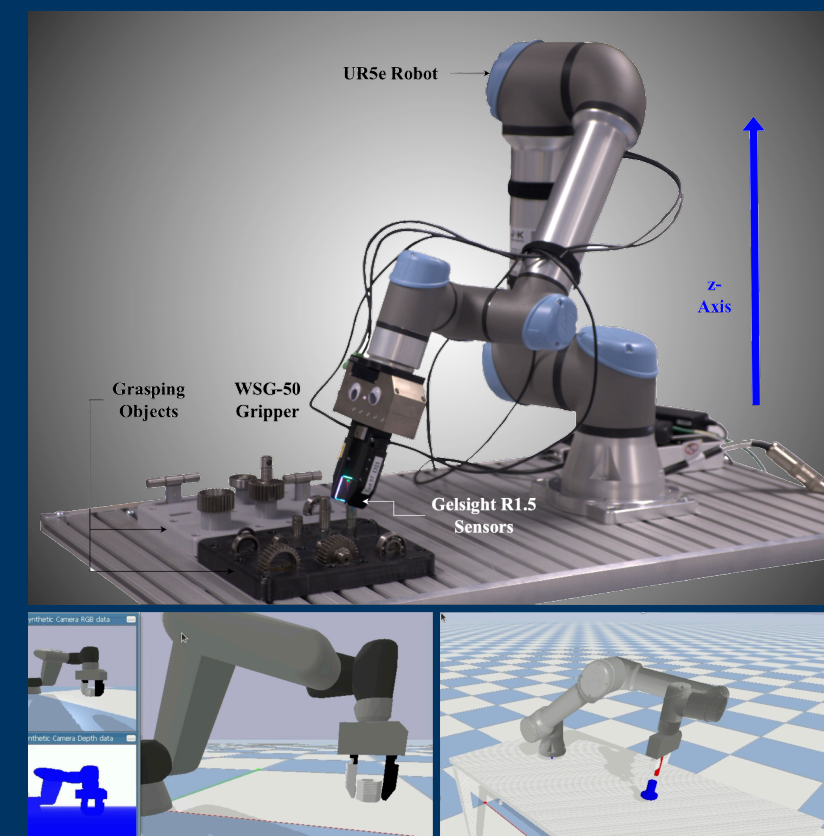
Modelling and Parameterisation

Mathematical Modelling

$$\begin{aligned} \dot{T}_{c1} &= \frac{1}{M_{c1}} (P_{c1} - P_{c2}) \\ \dot{T}_{c2} &= \frac{1}{M_{c2}} (P_{c2} - P_{c3}) \\ \dot{T}_{c3} &= \frac{1}{M_{c3}} (P_{c3} - P_{c4}) \\ \dot{T}_{c4} &= \frac{1}{M_{c4}} (P_{c4} - P_{c5}) \\ \dot{T}_{c5} &= \frac{1}{M_{c5}} (P_{c5} - P_{c6}) \\ \dot{T}_{c6} &= \frac{1}{M_{c6}} (P_{c6} - P_{c7}) \\ \dot{T}_{c7} &= \frac{1}{M_{c7}} (P_{c7} - P_{c8}) \\ \dot{T}_{c8} &= \frac{1}{M_{c8}} (P_{c8} - P_{c9}) \\ \dot{T}_{c9} &= \frac{1}{M_{c9}} (P_{c9} - P_{c10}) \\ \dot{T}_{c10} &= \frac{1}{M_{c10}} (P_{c10} - P_{c11}) \\ \dot{T}_{c11} &= \frac{1}{M_{c11}} (P_{c11} - P_{c12}) \\ \dot{T}_{c12} &= \frac{1}{M_{c12}} (P_{c12} - P_{c13}) \\ \dot{T}_{c13} &= \frac{1}{M_{c13}} (P_{c13} - P_{c14}) \\ \dot{T}_{c14} &= \frac{1}{M_{c14}} (P_{c14} - P_{c15}) \\ \dot{T}_{c15} &= \frac{1}{M_{c15}} (P_{c15} - P_{c16}) \\ \dot{T}_{c16} &= \frac{1}{M_{c16}} (P_{c16} - P_{c17}) \\ \dot{T}_{c17} &= \frac{1}{M_{c17}} (P_{c17} - P_{c18}) \\ \dot{T}_{c18} &= \frac{1}{M_{c18}} (P_{c18} - P_{c19}) \\ \dot{T}_{c19} &= \frac{1}{M_{c19}} (P_{c19} - P_{c20}) \\ \dot{T}_{c20} &= \frac{1}{M_{c20}} (P_{c20} - P_{c21}) \\ \dot{T}_{c21} &= \frac{1}{M_{c21}} (P_{c21} - P_{c22}) \\ \dot{T}_{c22} &= \frac{1}{M_{c22}} (P_{c22} - P_{c23}) \\ \dot{T}_{c23} &= \frac{1}{M_{c23}} (P_{c23} - P_{c24}) \\ \dot{T}_{c24} &= \frac{1}{M_{c24}} (P_{c24} - P_{c25}) \\ \dot{T}_{c25} &= \frac{1}{M_{c25}} (P_{c25} - P_{c26}) \\ \dot{T}_{c26} &= \frac{1}{M_{c26}} (P_{c26} - P_{c27}) \\ \dot{T}_{c27} &= \frac{1}{M_{c27}} (P_{c27} - P_{c28}) \\ \dot{T}_{c28} &= \frac{1}{M_{c28}} (P_{c28} - P_{c29}) \\ \dot{T}_{c29} &= \frac{1}{M_{c29}} (P_{c29} - P_{c30}) \\ \dot{T}_{c30} &= \frac{1}{M_{c30}} (P_{c30} - P_{c31}) \\ \dot{T}_{c31} &= \frac{1}{M_{c31}} (P_{c31} - P_{c32}) \\ \dot{T}_{c32} &= \frac{1}{M_{c32}} (P_{c32} - P_{c33}) \\ \dot{T}_{c33} &= \frac{1}{M_{c33}} (P_{c33} - P_{c34}) \\ \dot{T}_{c34} &= \frac{1}{M_{c34}} (P_{c34} - P_{c35}) \\ \dot{T}_{c35} &= \frac{1}{M_{c35}} (P_{c35} - P_{c36}) \\ \dot{T}_{c36} &= \frac{1}{M_{c36}} (P_{c36} - P_{c37}) \\ \dot{T}_{c37} &= \frac{1}{M_{c37}} (P_{c37} - P_{c38}) \\ \dot{T}_{c38} &= \frac{1}{M_{c38}} (P_{c38} - P_{c39}) \\ \dot{T}_{c39} &= \frac{1}{M_{c39}} (P_{c39} - P_{c40}) \\ \dot{T}_{c40} &= \frac{1}{M_{c40}} (P_{c40} - P_{c41}) \\ \dot{T}_{c41} &= \frac{1}{M_{c41}} (P_{c41} - P_{c42}) \\ \dot{T}_{c42} &= \frac{1}{M_{c42}} (P_{c42} - P_{c43}) \\ \dot{T}_{c43} &= \frac{1}{M_{c43}} (P_{c43} - P_{c44}) \\ \dot{T}_{c44} &= \frac{1}{M_{c44}} (P_{c44} - P_{c45}) \\ \dot{T}_{c45} &= \frac{1}{M_{c45}} (P_{c45} - P_{c46}) \\ \dot{T}_{c46} &= \frac{1}{M_{c46}} (P_{c46} - P_{c47}) \\ \dot{T}_{c47} &= \frac{1}{M_{c47}} (P_{c47} - P_{c48}) \\ \dot{T}_{c48} &= \frac{1}{M_{c48}} (P_{c48} - P_{c49}) \\ \dot{T}_{c49} &= \frac{1}{M_{c49}} (P_{c49} - P_{c50}) \\ \dot{T}_{c50} &= \frac{1}{M_{c50}} (P_{c50} - P_{c51}) \\ \dot{T}_{c51} &= \frac{1}{M_{c51}} (P_{c51} - P_{c52}) \\ \dot{T}_{c52} &= \frac{1}{M_{c52}} (P_{c52} - P_{c53}) \\ \dot{T}_{c53} &= \frac{1}{M_{c53}} (P_{c53} - P_{c54}) \\ \dot{T}_{c54} &= \frac{1}{M_{c54}} (P_{c54} - 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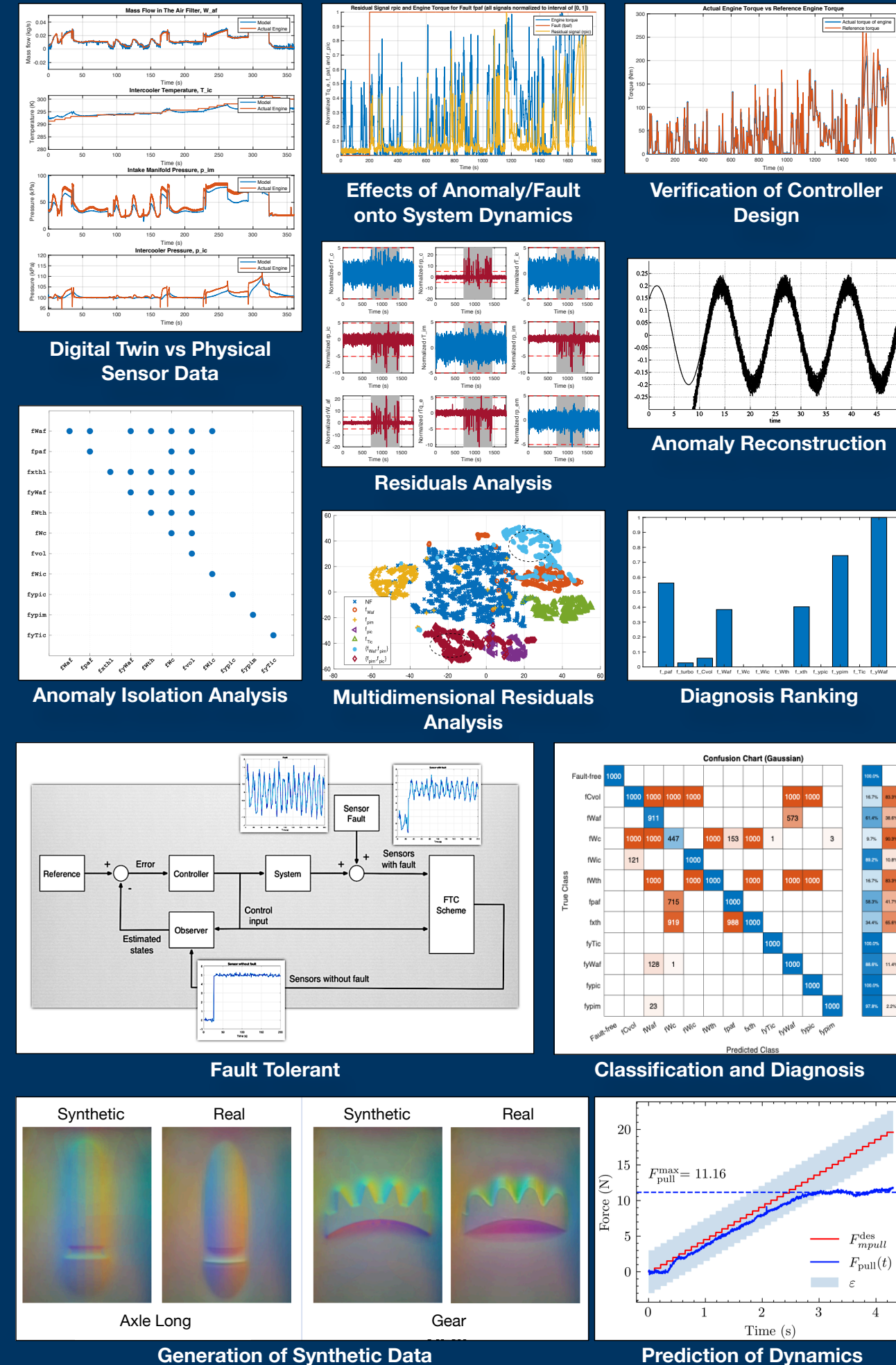


Digital Twin, Digital Shadow, and Simulation Testbed



Manufacturing

Prediction of Dynamics and Maintenance, Fault/Anomaly Diagnosis, Availability and Sustainability Analysis, Personalised Healthcare, Simulated Surgery, Improved Diagnosis, etc.



*Actual simulated and diagnosis results

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Select Key Publications

- "A Realistic Simulation Testbed of A Turbocharged Spark Ignited Engine System: A Platform for the Evaluation of Fault Diagnosis Algorithms and Strategies", *IEEE Control Systems Magazine*, 2020. DOI:10.1109/MCS.2019.2961793
- "Design and Selection of Additional Residuals To Enhance Fault Isolation of A Turbocharged Spark Ignited Engine System", *7th International Conference on Control, Decision and Information Technologies (CoDIT)*, Prague, Czech Republic, 2020. DOI:10.1109/CoDIT49905.2020.9263792
- D. Jung, K. Y. Ng, E. Frisk, and M. Krysander (2018), "Combining model-based diagnosis and data-driven anomaly classifiers for fault isolation", *Control Engineering Practice*, 2018. DOI:10.1016/j.conengprac.2018.08.013
- "A Sliding Mode Observer for Infinitely Unobservable Descriptor Systems", *IEEE Transactions on Automatic Control*, 2017. DOI:10.1109/TAC.2017.2665699
- "A combined diagnosis system design using model-based and data-driven methods", *IEEE 3rd Conference on Control and Fault-Tolerant Systems (SysToI)*, Barcelona, Spain, 2016. DOI:10.1109/SYSTOL.2016.7739747
- "Predicting Maximum Permitted Process Forces for Object Grasping and Manipulation Using a Deep Learning Regression Model", *8th IEEE Conference on Control Technology and Applications (CCTA)*, Northumbria University, UK, 2024. DOI: 10.1109/CCTA60707.2024.10666569
- "Artificial intelligence in smart manufacturing: Emerging opportunities and prospects", *Artificial Intelligence for Smart Manufacturing and Industry X.0*, Springer Nature, 2025. DOI: 10.1007/978-3-031-80154-9_2
- "Learning to Predict Grip Quality from Simulation: Establishing a Digital Twin to Generate Simulated Data for a Grip Stability Metric", *arXiv preprint*, 2023. DOI: 10.48550/arXiv.2302.03504

Digital Twin to Generate Simulated Data for a Grip Stability Metric

Stefanie Wucherer, Robert McMurray, Kok Yew Ng, and Florian Kerber

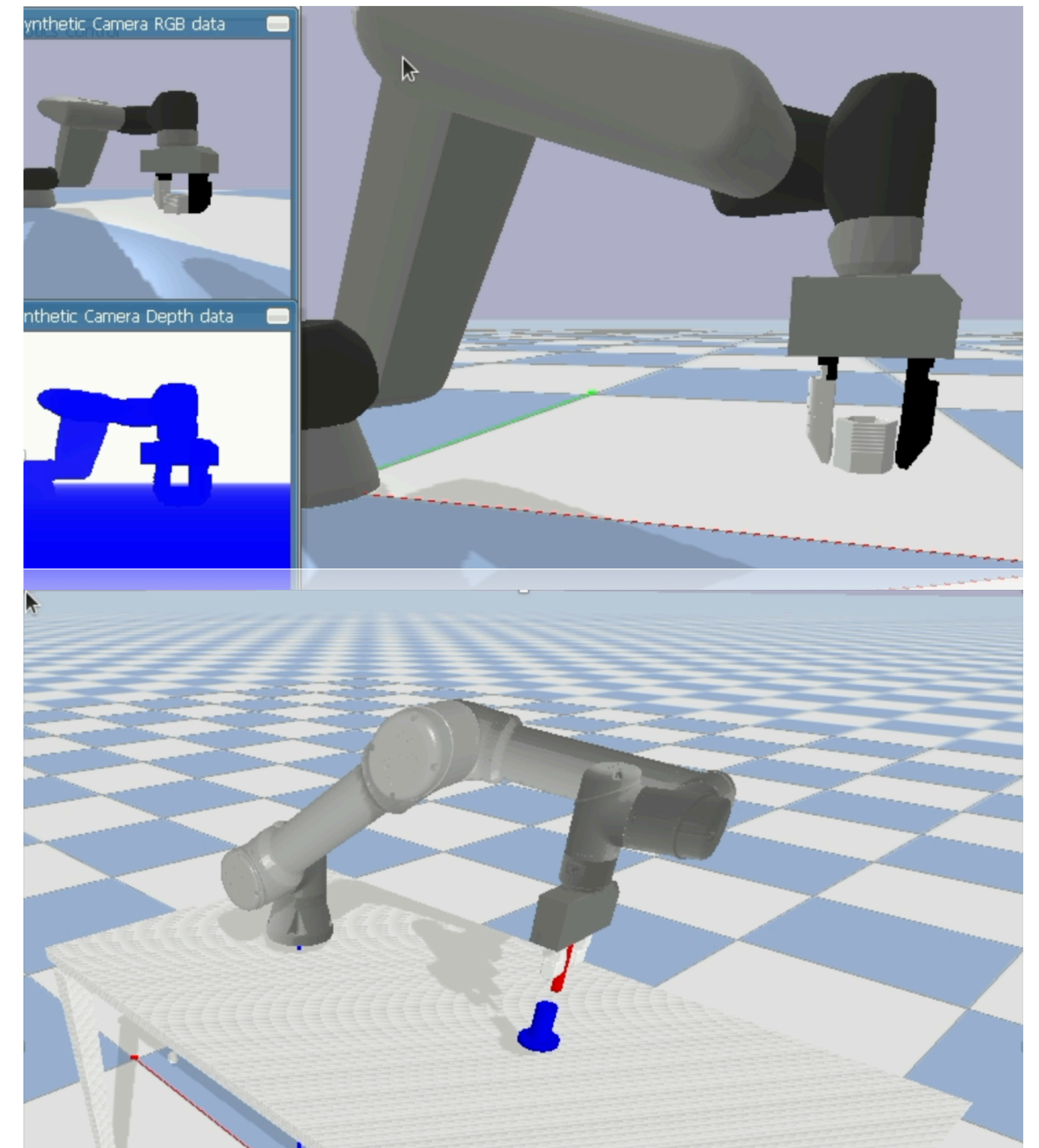
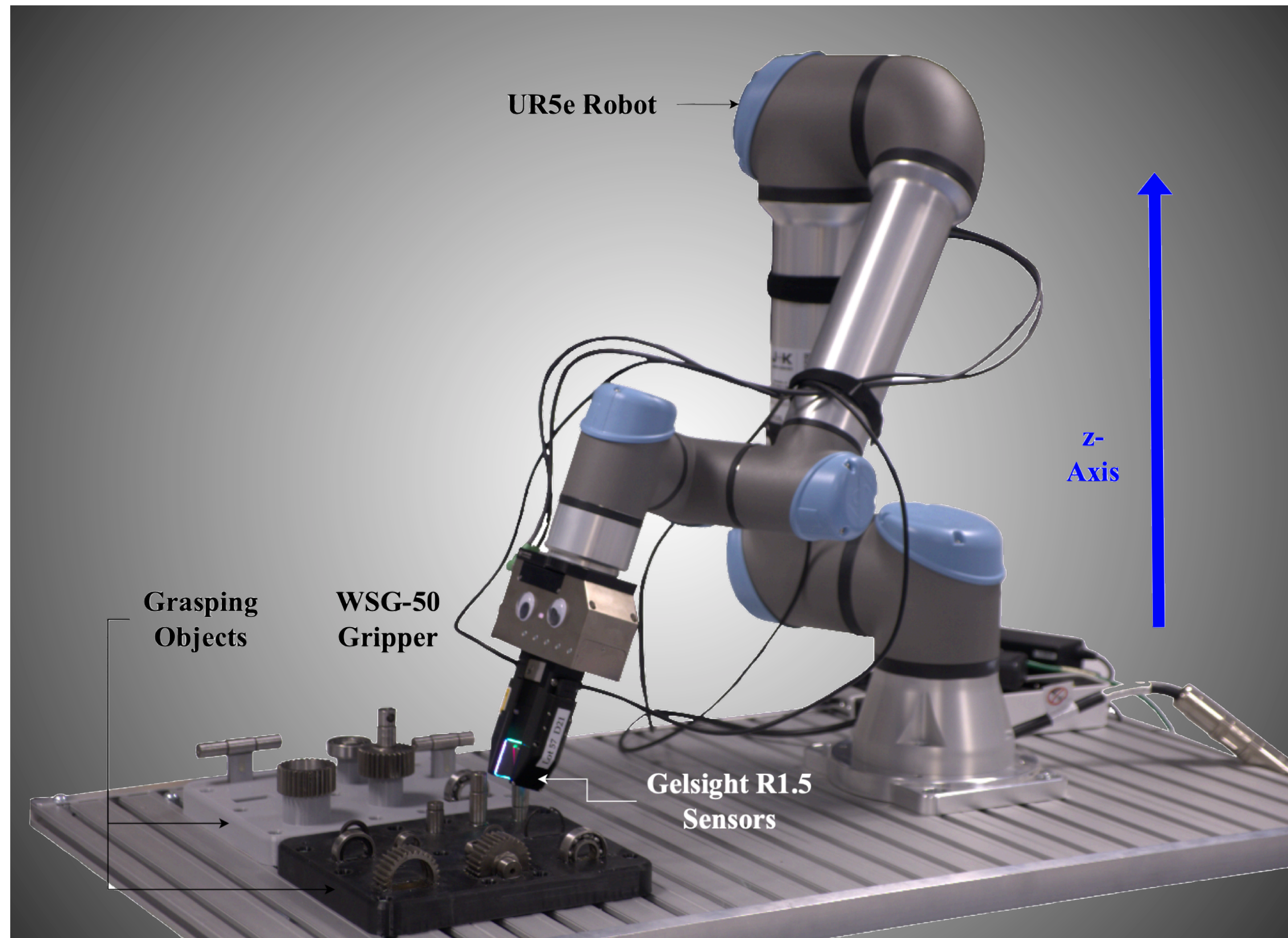


Technische
Hochschule
Augsburg

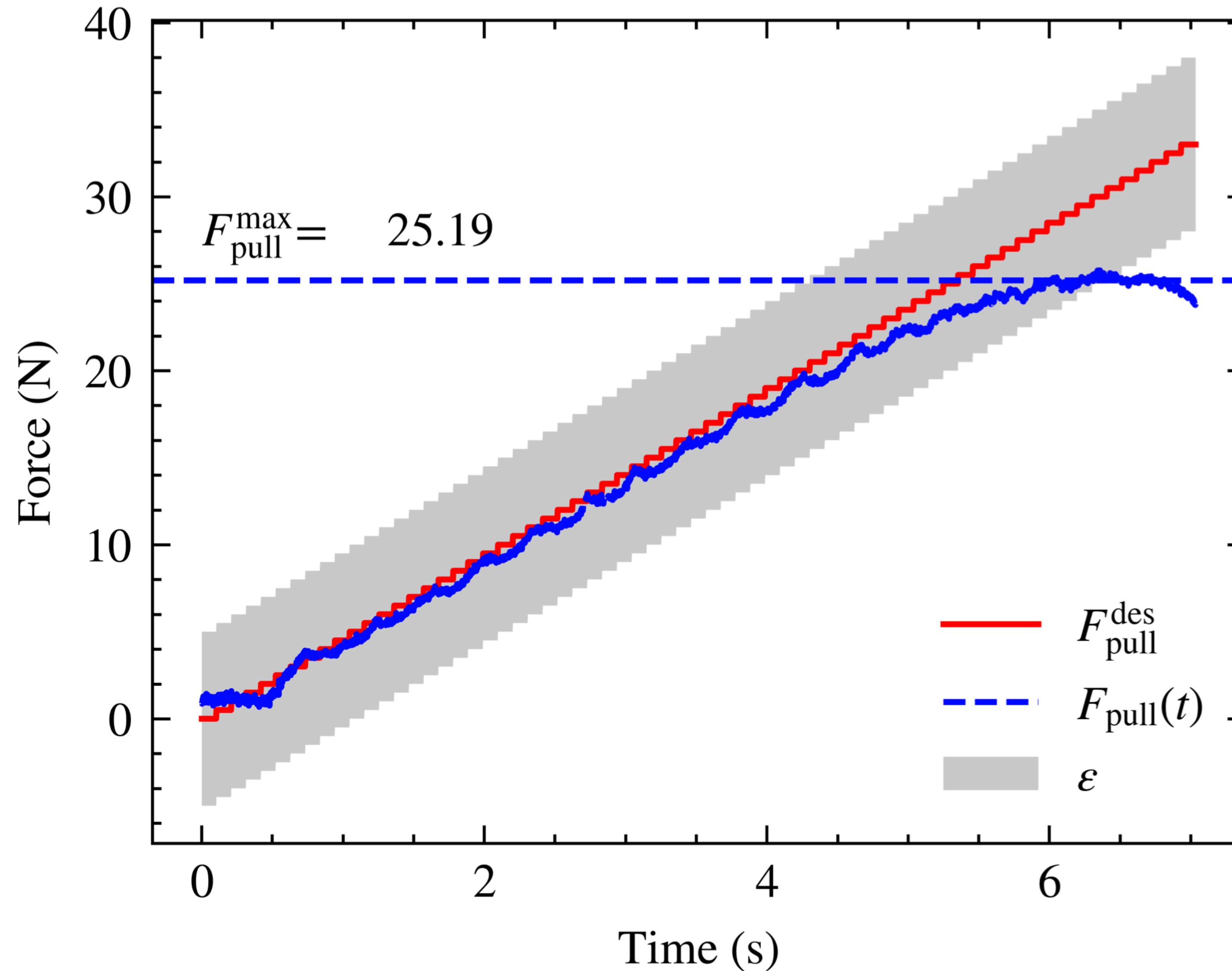


TTZ Nördlingen
Flexible Automation

Physical Setup vs Digital Twin



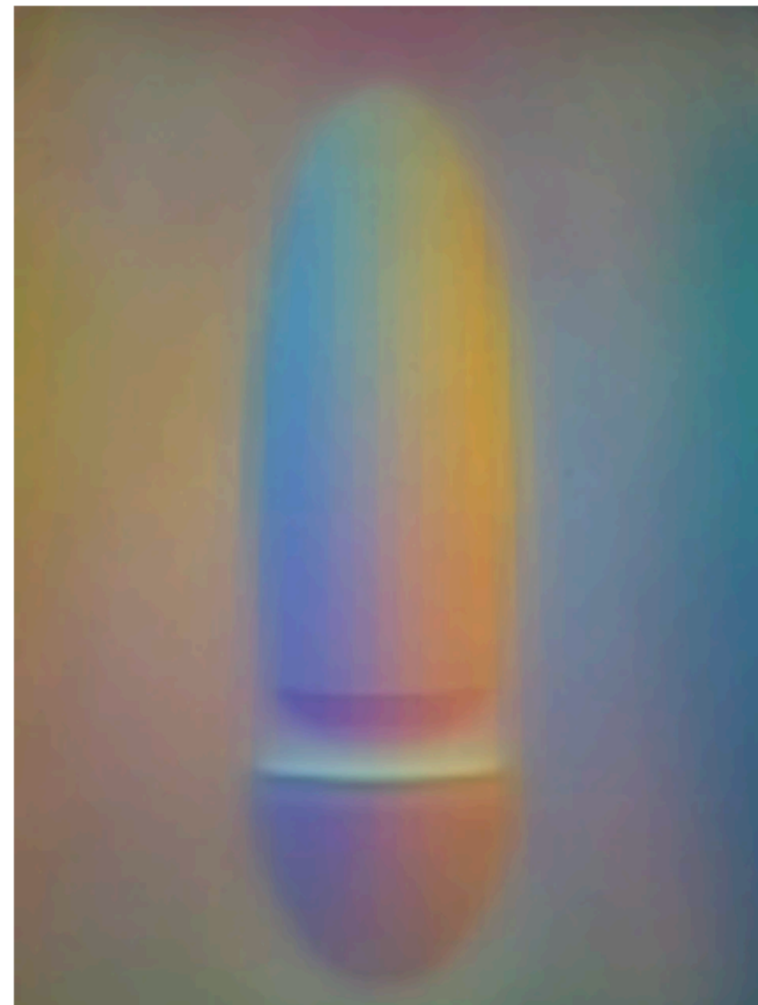
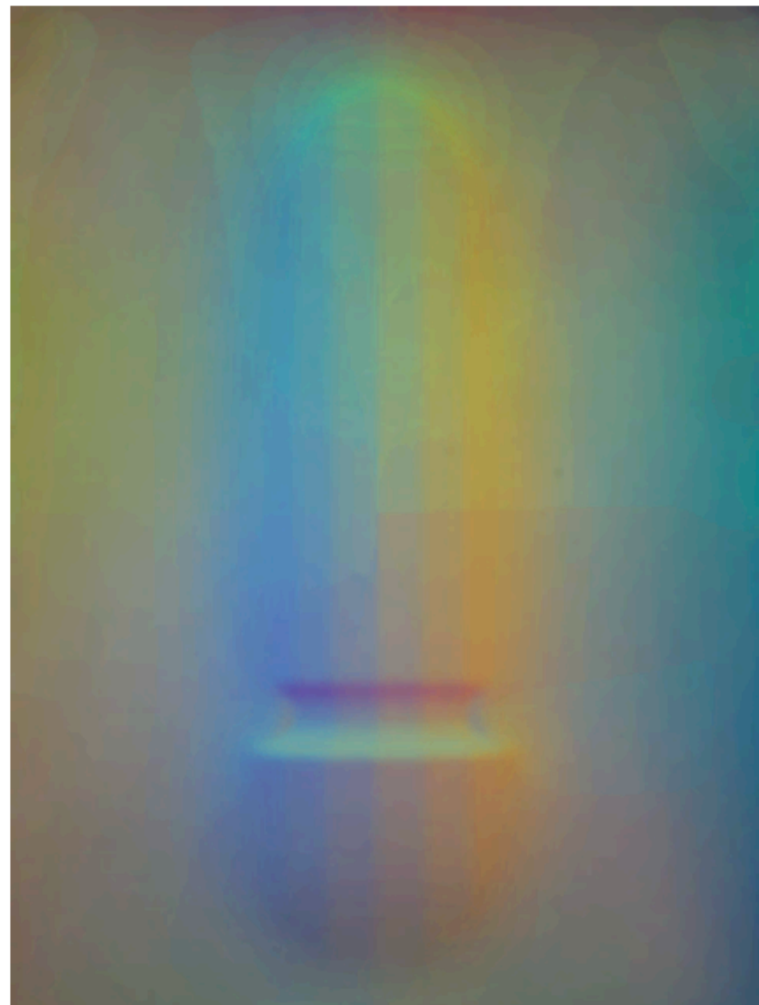
Prediction of Grip Force Using Deep Learning



Generation of Synthetic Data for Existing and Potential Future Assembly Parts

Taxim

Real

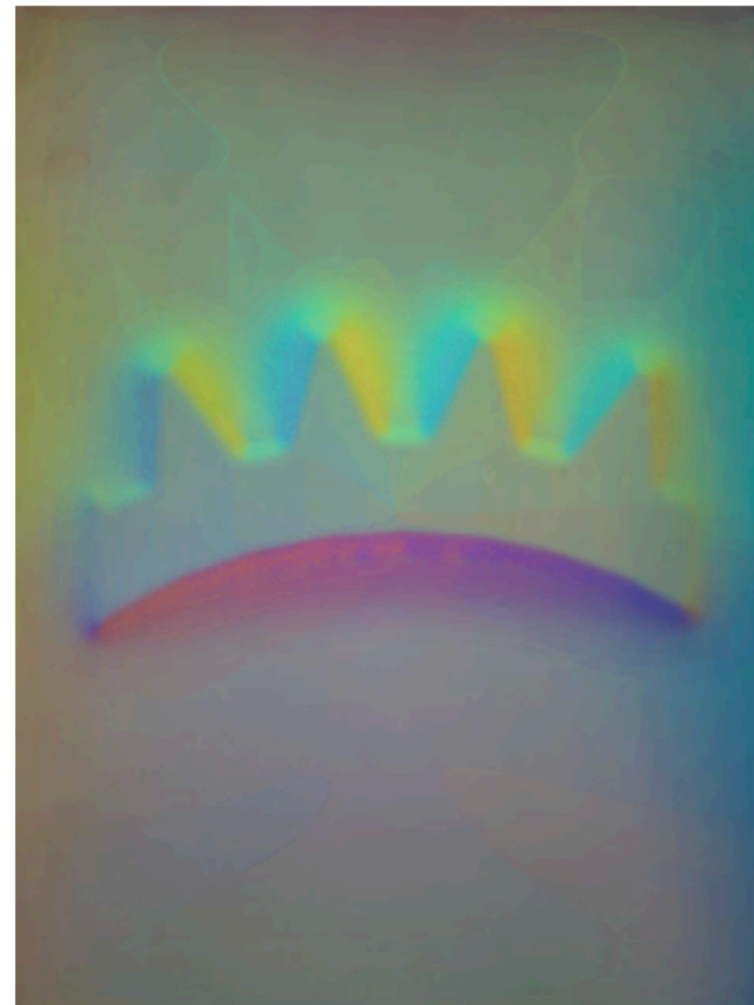


Axle long

gnol gniA

Taxim

Real

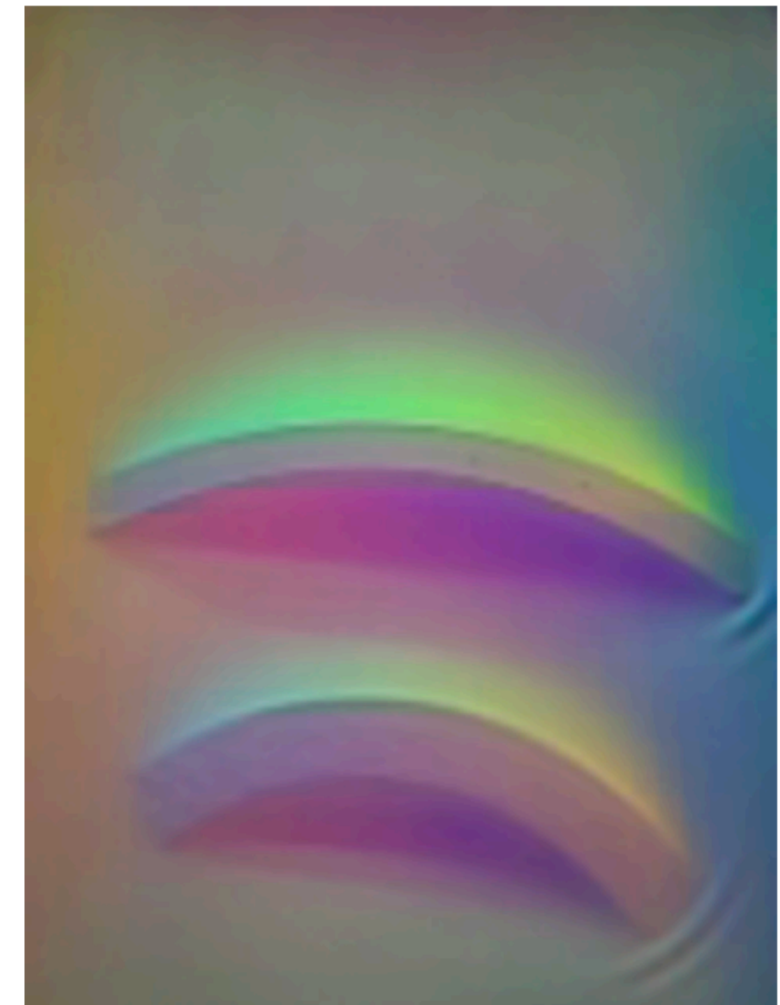


Gear

cegnI

Taxim

Real



Ball bearing

Bgll pcegnI